UCL Institute for Environmental Design and Engineering

Engineering Sustainability

Devising a suitable sustainability education intervention for the Nigerian engineering curriculum

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Declaration

I, Usman Akeel, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

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Abstract

Despite its commitment to global sustainability pacts, Nigeria does not currently have a framework for sustainability in engineering education. This study aims to formulate a sustainability education intervention for the Nigerian engineering curriculum. Using the mixed-method approach, the study assessed the level of sustainability knowledge of the Nigerian engineering community, examined the sustainability content of the Nigerian engineering curriculum, and proposed a context-relevant sustainability education intervention. Data for the study were sourced variously from publications of regulatory bodies, engineering handbooks, surveys and workshops with stakeholders. The Nigerian engineering community was discovered to have low sustainability literacy based on a sustainability literacy test, level of stakeholder awareness of the United Nations Decade of Education for Sustainable Development, and self-assessment of sustainability knowledge. Both content analysis and stakeholder survey converged on the low sustainability content of the Nigerian engineering curriculum.

With insights gained from the findings, a bipartite intervention consisting of a guideline and an introductory sustainable engineering course is proposed. Whilst the guideline specifies roles for government, regulators, university leaders and faculty, the designed course features 15-weekly topics for adoption in the engineering handbooks. Aspects of the proposed course trialled in a sustainable engineering workshop indicated favourable prospects for the introduction of the course. Workshop participants were unanimous in declaring the usefulness and expediency of sustainability education in the Nigerian engineering curriculum. Although the research findings are particularly relevant to the Nigerian engineering curriculum, the study confirms the slow uptake of sustainability education in the developing world. By closely examining the feasibility of sustainability education intervention in engineering curriculum in a different cultural and social setting, the research contributes to the global efforts towards the reorientation of engineering education to sustainability.

Dedication

This work is dedicated to my dear parents - Engr. Umar Akeel and Hajia Daharatu Bala.

...best parents ever!

Acknowledgements

Trailing the attainment of every piece of knowledge is an ineffable emotion – the experience of moving from a state of ignorance to a state of knowing. However, such intellectual journey is almost always impossible without the support and guidance of several great people – evocative of Newton's "*standing on the shoulders of giants*" remark. My knowledge journey through this research has benefited from the guidance and support of many great minds. Prof Sarah Bell and Prof John Mitchell critiqued and provided valuable suggestions that enriched the research outcomes. Thank you for being an amiable professorial duo and for your excellent supervision of the thesis! Additionally, I am obliged to Prof Folagbade Oriola, Dr Yahaya Muhammad and Mr Julius Adamu for facilitating the conduct of surveys in the various institutions involved in the study. Without your personal sacrifices, the research process would have been much more difficult.

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This acknowledgement will be incomplete without expressing appreciation to my parents and siblings for the unceasing love and well-wishing. Thank you for being a doting family! If I were endowed with total recall, I would mention all the people with whom I have interacted and exchanged ideas in the course of my educational sojourn, for such interchange must have undoubtedly contributed in one way or another to building me intellectually. This not being the case, however, I will mention one person and then go no further – my darling wife, Halima. She deserves commendation for her patience, forbearance, unconditional love and emotional support. Thank you Halima for creating a serene and pleasant home during the period of my study, especially on the days of despondency and nights of gloom!

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Abbreviations

AAU	Association of African Universities
ABU	Ahmadu Bello University
AEEA	African Engineering Education Association
ASEE	American Society for Engineering Education
ASK	Assessment of Sustainability Knowledge
BMAS	Benchmark Minimum Academic Standards for Engineering
CDIO	Conceive, Design, Implement and Operate
CERES	Coalition for Environmentally Responsible Economies
COREN	Council for the Regulation of Engineering in Nigeria
EBL	Enquiry-Based Learning
EER	Engineering Education Research
EESD	Engineering Education for Sustainable Development
EEZ	Exclusive Economic Zone
EHEA	European Higher Education Area
EIPs	Eco-Industrial Parks
ESD	Education for Sustainable Development
ER	Educator Respondent
FEPA	Federal Environmental Protection Agency
FME	Federal Ministry of Education
FMEnv	Federal Ministry of Environment
GHESP	Global Higher Education for Sustainable Development Partnership
HEI	Higher Education Institution
IAU	International Association of Universities
JAMB	Joint Admissions and Matriculation Board
LCA	Life Cycle Assessment
LEED	Leadership in Energy and Environment Design
NAE	Nigerian Academy of Engineering
NDA	Nigerian Defence Academy
NECO	National Examinations Council
NEP	National Environmental Policy

NESREA	National Environmental Standards and Regulations Enforcement Agency
NPE	National Policy on Education
NSE	Nigerian Society of Engineers
NUC	National Universities Commission
OSSAP-MDGs	Office of the Senior Special Assistant to the President on Millennium Development Goals
OSSAP-SDGs	Office of the Senior Special Assistant to the President on Sustainable Development Goals
PBL	Problem-Based Learning
PjBL	Project-Based Learning
PR	Practitioner Respondent
PWD	Public Works Department
RAE	Royal Academy of Engineering
RCE	Regional Centre of Expertise
SDGs	Sustainable Development Goals
SHE	Sustainable Higher Education
SLT	Sustainability Literacy Test
SR	Student Respondent
STAUNCH®	Sustainability Tool for Assessing Universities Holistically
UNCED	United Nations Conference on Environment and Development
UNCSD	United Nations Commission on Sustainable Development
UNDESD	United Nations Decade of Education for Sustainable Development
UNGA	United Nations General Assembly
UNU	United Nations University
UNWCED	United Nations World Commission on Environment and Development
WAEC	West African Examinations Council
WCHE	World Conference on Higher Education
WEPSD	World Engineering Partnership for Sustainable Development
WFEO	World Federation of Engineering Organisations
WSSD	World Summit on Sustainable Development

Preface

As an engineering student in Nigeria in early 2000s, I could not rationalise some of the courses I was being taught at the university. It made little sense to me why, as a civil engineering student, for example, I needed to undertake courses such as *economics management science* and *engineering geology*. Although I was unable to discern how these courses, even remotely, related to civil engineering, I made sure that I passed them satisfactorily. It however registered on my mind that something was amiss about the engineering education in my higher education institution (HEI), or at the least, with its civil engineering syllabus. Operating within a non-democratic pedagogical setting, my HEI did not provide much opportunity for questioning the rationale of a course. Compounding the situation were a packed curriculum and lack of alternative sources of information (such as Internet); it was a typical teacher-centred learning environment.

A few years after graduation, I met graduates of several engineering disciplines from other Nigerian HEIs at an engineering conference. It was an opportune moment to share knowledge and experiences including thoughts on the Nigerian engineering education system. It emerged from the discussions that my experience with the civil engineering syllabus was in no way unique. Many of the engineering graduates claimed to have also inadequately understood the philosophy of various courses in the engineering curriculum. I felt, all at once, a sense of relief and disenchantment. I was relieved that my incomprehension of the philosophies of those civil engineering courses did not result from an intellectual deficit (as it seemed shared across disciplines and HEIs). However, I was worried about the implication of this deficiency on the Nigerian engineering community. Questions such as "*why is there a cosmic disconnect between a taught engineering course and a student's appreciation of its relevance?"* formed on my mind.

In the meantime, I gained employment with the Logistics Branch of Nigerian Air Force (NAF). My occupation ranged from supervision of civil engineering works and infrastructure maintenance to instruction on civil engineering courses at the Nigerian Air Force Institute of Technology (NAFIT). My involvement in civil engineering projects exposed me to the dilemma of Nigerian engineering graduates whose lack of adequate practical experience is repeatedly invoked to deny them employment. Through interaction with engineering educators and practising engineers over the years, I became convinced that the shortcomings I had observed both as an undergraduate student and as an employee of the NAF were symptomatic of a larger issue. Since its development based on the 1960s UK model, the Nigerian engineering education system has had an inchoate and incomprehensive review and/or modification. This is even apart from the commonly discussed problems of funding and inexpert teaching.

In 2009, I had an opportunity to travel to the UK for a master's degree programme here at UCL. I realised that whilst Nigeria was stuck with an inchoately modified 1960s UK model of engineering curriculum, the UK engineering education framework in 2009 had markedly advanced. I was impressed by the obvious efforts of lecturers to employ various student-centred approaches including case-study and problem-based learning methods to facilitate knowledge. Each time I observed an unfamiliar and seemingly valuable pedagogical technique, I imagined how it could be replicated in Nigeria. In retrospect, this was a truly naïve view of educational change as social and cultural contexts are now consensually accepted to be key in any transformational move. In any event, it was of particular interest to me that I fully grasped the relevance of all the courses I undertook during the master's degree programme. Somehow the connection between the courses had been established by an intricate interaction within the engineering education system.

Having completed my master's degree in 2010, I returned to my job with the NAF in Nigeria. However, my desire to investigate and find ways of improving the Nigerian engineering education had been reinforced. When the opportunity for me to undertake a doctoral research arose in 2015, I felt obliged to utilise it towards this effort. Educational change within the framework of sustainability proved quite a compelling research area for the changes I had envisioned. The more I read about sustainability education the greater I was persuaded by its prospect to facilitate holistic educational reforms. It can help address the challenges of the Nigerian engineering education whose cues I had observed in the incompact engineering syllabus and in the so-called unemployable graduates. This research is thus driven by an enduring urge to bring about a positive change in an educational system through which I passed. If it succeeds in as little as showcasing how the principles of flexibility and eclecticism in sustainable engineering education facilitate protean engineering graduates, the study will have been fulfilling and worthwhile.

Chapter One

1 Introduction

Background

In recent memory, the impacts of manipulating nature for human benefit have been subjected to political, ethical, moral and intellectual interrogations. An important outcome of these reflections is the concept of sustainable development, which seeks the attainment of economic growth, environmental protection and social responsibility. Some of the crises that triggered sustainability advocacy included biodiversity loss, climate change, heightened water demand, poverty, carbon emissions and hyper-consumerism. Engineering, being the principal facilitator of socioeconomic progress, is implicated in these unprecedented global challenges. To stem these problems, the dominant engineering model must be reconsidered – hence the emergence of sustainable engineering. Sustainable engineering offers a conceptual departure from conventional engineering by broadening the problem and solution domains of engineering across the sustainability pillars of economy, society and environment.

Sustainable engineering seeks to conduct engineering activities within a sustainability worldview, which is poised to induce in individuals the cognitive orientation necessary to make sense of an increasingly complex and unpredictable world (Allenby, 2007). The global challenges facing the world in the 21st century have been attributed to the arrival of an epoch: the Anthropocene (Age of the Human). Anthropocene describes a geologic period of heavily human-impacted Earth in which the complex interconnectedness of humans with the natural and built systems is pervasive (Ellis and Trachtenberg, 2014). Sustainability worldview acknowledges this complexity and defines solutions in terms of a balance among economic growth, social responsibility and environmental integrity. Human activities must occur within such framework in order to attain the prized goals of sustainable development (Ehrenfeld and Hoffman, 2013).

Sustainability education emerged in a contiguity of international declarations and conferences to mainstream sustainability values into the educational system. Worried by the slow uptake of sustainability ideals and practices globally, the international community responded with a succession of various sustainability-related conferences. Education was unanimously declared to be critical to the realisation of sustainable development. In 2004, the United Nations proclaimed the period 2005-2014 as the Decade of Education for Sustainable Development (UNDESD). This period witnessed heightened global calls and efforts at mainstreaming sustainability education into various institutions and countries. Further meetings, deliberations and research pointed to the significance of higher education institutions (HEIs) in the implementation of sustainability education. As a result, sustainability education initiatives were introduced in many universities. The Barcelona Declaration (EESD, 2004) signified the response of the engineering education community to sustainability education. Since its issuance in 2004, the Declaration has guided the discourse of engineering education for sustainability. An observatory was established in Catalonia to monitor the progress of sustainable engineering education worldwide.

Designed chiefly in a developed world context, the theory and practice of sustainable engineering education has failed to gain much traction in the developing world. In spite of their expeditious signing of several sustainability education declarations, developing nations are somewhat hesitant about sustainability education initiatives. This has raised concerns about the encumbrances of sustainability education in those regions. Prominent amongst these constraints, particularly in Africa, are human development priorities. Over 90% of the low human development countries are located in Africa (UNDP, 2016b). The continent faces unique socioeconomic challenges that severely limit the trade-off between societal needs and environmental consumption. Grappling with issues of multidimensional poverty, most African countries tend to relegate the so-called green initiatives. The constant refrain is that such policies slow down the much-needed economic growth. There is an underlying sentiment that the developed countries have attained high human development without due regard to environmental concerns (Iqbal and Pierson, 2016). Thus, it is only fair that the developing countries have the same opportunity. This is a classic North-South debate on the implications of sustainable development, which also extends to sustainability education.

Notwithstanding the allure and cogency of the fairness argument, the prevailing circumstances in the developing world and the world at large are not propitious for the past developmental model of the West. Estimates show that almost 90% of population increase will occur in the developing world (Iqbal and Pierson, 2016). There are also issues of climate change and its attendant consequences. Evidence shows that the carbon dioxide concentration in the atmosphere has increased from pre-industrial levels of 280 parts per million by volume (ppmv) to around 387 ppmv in 2008 (Bell, 2011). These changed environmental conditions call for a sustainable development model. However, whilst research into sustainable engineering education has generally increased, few of these studies have focused on the developing world. Even fewer studies have been conducted in the context of sub-Saharan Africa. Nevertheless, sustainability challenge demands the involvement of the entire global community. Additionally, it is futile that one part of the world takes sustainability concerns seriously whilst another part remains apathetic to the global challenges. Partly to address these apprehensions, the United Nations created alongside the UNDESD the Mainstreaming Environment and Sustainability in African Universities Partnership (MESA). The MESA baseline study in 2004 indicated that sustainability education in African HEIs was merely an emerging interest (UNEP-MESA, 2009).

Nigeria is one of the African countries referenced in the MESA study. As an active member of the global community, Nigeria has consistently responded to international calls for sustainability and environmental protection. Although it had signed a number of international pacts since gaining independence in 1960, Nigeria began to take seriously sustainability-related matters in the 1980s. Precisely, 1987 was a watershed in Nigeria’s environmental and sustainability history. In the wet season of that year, it emerged that large amounts of toxic wastes from Italy had been dumped in Nigerian waters. An increased number of environmental policies and institutional frameworks to protect national resources trailed this environmental disaster. With the emergence of numerous protection measures arose the need for expertise in environmental knowledge. In response to this necessity, environmental education developed and gradually permeated several Nigerian HEIs. Presently, environmental programmes in Nigeria converge in either environmental management or environmental engineering degrees. These formed part of the baseline data obtained by the 2004 MESA study, which pointed to a slow progress of sustainability education in Nigeria.

The Nigerian engineering education system responded to sustainability education with an environmental focus. Environmental engineering became the dominant area within which sustainability was taught and learned. This implied a narrowing of sustainability to only the environmental component of sustainability at the expense of the social and economic dimensions. Nigeria's ratification of the Abuja Declaration which sought the implementation of ESD in African HEIs in 2009 was greeted with high expectations. However, the pact generally failed to yield any concrete initiatives. There is no reference to sustainability education in Nigerian educational policies and no mention of a sustainable engineering degree in the higher education programmes listed in the most recent brochure of the Nigerian Joint Admissions and Matriculation Board (JAMB, 2017). This could be construed as a complete absence of sustainability education in the Nigerian HEIs in so far as sustainability education is understood strictly within the framework of education for sustainable development (ESD), i.e. reorienting policy, investment and practice of education on a sustainability path (ESD, 2014). Although it can be held that no Nigerian HEI currently offers a sustainable engineering degree, however the prospect of introducing such courses and aligning extant ones with sustainability ideals is propitious.

In a recent study of sustainability education in Africa, Manteaw (2012) described how African governments readily accepted the ESD agenda only to later withdraw into inaction and non-commitment. Manteaw raised issues of capacity, lack of political commitment and absence of institutional support as contributory to the poor status of ESD in most African countries. Other constraints highlighted in similar studies included cultural barriers and poor grasp of sustainability concepts, which have largely led to failure by African societies to connect sustainability education agenda with their regional experiences (Shallcross and Robinson, 2007). Although this view has been copiously supported in the literature (Thakran 2004; Leal Filho et al. 2007; Jenneth & Ros 2008; Manteaw 2012; UNESCO 2013), a country-specific investigation will reveal more details and suggest suitable sustainability education interventions. Along these lines, AI Phuong (2013) and Sivapalan (2015) conducted sustainable engineering education studies in Vietnam and Malaysia respectively. Their findings did not only add to existing knowledge on regional sustainability education status but also lent credence to the effectiveness of planning sustainable engineering education based on local relevance and cultural appropriateness.

This study contextualises sustainable engineering education in Nigeria. The purpose of the research is to explore the prospect of a sustainability intervention in the Nigerian engineering education. The study seeks an evidence-based implementation strategy for the Nigerian engineering curriculum. It queries the level of sustainability knowledge of the Nigerian engineering community, examines the sustainability content of the Nigerian engineering curriculum, and seeks an appropriate sustainability education intervention for effective and meaningful impact in the Nigerian engineering education. The research involves an analysis of sustainability education literature, publications of professional and regulatory bodies in Nigeria, surveys and workshops administered to stakeholders in the Nigerian engineering community. The study intends to show that a sustainable engineering education for Nigeria is feasible with insights gained from stakeholder participation and global best practice. Situating the research in a sub-Saharan African setting has the benefit of consolidating the criticality of context in not only sustainable engineering education, but also engineering curricular development. Also, the focus of the study on a previously unexplored context[1] will be a modest addition to global sustainability education efforts.

Aim

The aim of the research is to formulate an appropriate sustainability education intervention for the Nigerian engineering curriculum.

Research Questions

1. What is the current level of sustainability knowledge of the Nigerian engineering community?

2. What is the sustainability content of the Nigerian engineering curriculum?

3. What sustainability education interventions are appropriate for the Nigerian engineering curriculum?

[1] Based on an extensive literature review, personal experience both as a student and lecturer, and recent communication with Nigerian academics, sustainability education in the context of Nigerian engineering curriculum has, to-date, not been researched into.

Thesis Outline

Chapter One provides a background to the study stating the scope, aim and questions to which the research seeks answers. It makes the case for a sustainability education intervention in the Nigerian engineering curriculum based on the following facts. Firstly, that the increased global efforts to reorient engineering education towards sustainability have largely been confined to the developed nations. Secondly, that Nigeria does not currently have a sustainability education framework within which sustainable engineering can be taught. Thirdly, that the global nature of sustainability challenge demands the involvement of the entire global community. Finally, that the prospect of an intervention in the Nigerian engineering curriculum is research-worthy.

Chapter Two is a selective review of the literature on sustainability and sustainability education in engineering. This chapter offers a concept clarification of sustainability and highlights the continuing efforts at teaching and learning about sustainability. Through the lens of three educational aims, namely *salvation, the state,* and *progress*, the chapter reviews sustainability education declarations and sustainability education construct. Thereafter, it critiques the construct which provides the impetus for the appraisal of sustainability education in engineering. The conception and origins of sustainable engineering as a conceptual departure from conventional engineering practice alongside the principles, tools, and frameworks of the field are discussed. The chapter also highlights the application of sustainable engineering and the pedagogical approaches in sustainability education. The chapter ends with an overview of research in sustainable engineering education stressing the need for more investigations in the developing world context.

Chapter Three focuses on the research context of the present study – Nigeria. It presents the prevailing status of sustainability education in Nigeria as it relates to the engineering curriculum. The chapter highlights the practice of engineering in Nigeria, the role of Nigerian educational system, and how Nigerian engineers are typically educated. Sustainability issues including the dumping of hazardous wastes in Nigerian waters by an Italian company and the resulting environmental policies are addressed. The chapter also underlines a gap in the body of knowledge presented as the dearth of sustainability education research in the Nigerian engineering education.

Chapter Four sets out the overall methodological framework for the present research. It recaps the research questions and discusses various sustainability assessment approaches vis-à-vis sustainability content, sustainability literacy and sustainability learning process. The chapter then highlights the research approach, research paradigm and research design adopted in the study. Thereafter, the methods of data collection and data analysis are discussed before considering the validity, reliability, and ethical issues of the study.

Chapter Five gauges the level of sustainability knowledge of the Nigerian engineering community. It responds to the question around the general sustainability awareness of the Nigerian engineering community. The chapter introduces three criteria against which the sustainability literacy level of the community is measured including the level of UNDESD awareness, score on a sustainability literacy test, and self-assessment of sustainability knowledge. The chapter proceeds by describing the students' results followed by those of the educators and practitioners. The results are synthesised to approximate the sustainability literacy level of the entire engineering community. The chapter concludes with a discussion of the results and limitations of the study.

Chapter Six addresses the question of the sustainability content of the Nigerian engineering curriculum. It analyses three engineering documents obtained variously from engineering regulatory bodies and higher education institutions in Nigeria. The chapter also examines the perspectives of engineering stakeholders to complement the documentary analysis. The documents and stakeholder views are tested against *a priori* codes obtained from a set of expert-derived sustainability themes. UCL engineering curriculum is also assessed and compared with the Nigerian engineering curriculum. The chapter begins by presenting the results of the documentary analyses followed by those of the stakeholder views. Both results are subsequently synthesised to estimate the sustainability content of the Nigerian engineering curriculum.

Chapter Seven responds to the question regarding the appropriate sustainability education interventions for the Nigerian engineering curriculum. Answers to the question are informed by the insights gained from the study as well as stakeholder responses to a survey. The chapter proceeds by stating some useful intervention cues before analysing the stakeholders' views on the numerous sustainability education intervention approaches. The chapter concludes with a discussion of the findings and limitations of the study.

Chapter Eight formulates an intervention for the Nigerian engineering curriculum. A bipartite intervention featuring guidelines and an introductory course on sustainable engineering is presented. The intervention is proposed based on the insights from the chapters. The chapter begins with a delineation of the intervention requirements arising from the analysed data. Thereafter, the details of the intervention are provided. The chapter then trials a sustainable engineering course by means of a sustainability workshop assessing the prospect of running a sustainable engineering course in a Nigeria. It presents an overview of the workshop, layout, preliminary assessments and a presentation on sustainable engineering. The chapter concludes with a discussion of the findings and limitations of the study.

Chapter Nine concludes the thesis and highlights the contribution and further work emanating from the study. It underscores the usefulness and expediency of the proposed sustainability education intervention for the Nigerian engineering curriculum.

Summary

This chapter provided a background to the study with a view to making a case for sustainability education intervention in Nigerian engineering curriculum. It presented the scope, aim, research questions and methodology of the research. Table 1.1 presents a matrix depicting some of the main elements of the thesis.

Table 1.1. Summary of thesis elements

Research Question	Research Tool(s)	Relevant Chapter(s)
What is the current level of sustainability knowledge of the Nigerian engineering community?	Sustainability Literacy Test Stakeholder Survey	Chapter Five: Sustainability Literacy of the Nigerian Engineering Community
What is the sustainability content of the Nigerian engineering curriculum?	Documentary Analysis Stakeholder Survey	Chapter Six: Sustainability Content of the Nigerian Engineering Curriculum
What sustainability education interventions are appropriate for the Nigerian engineering curriculum?	Workshop Stakeholder Survey	Chapter Seven: Sustainability Education Intervention for Nigerian Engineering Curriculum Chapter Eight: Formulating an Intervention for Nigerian Engineering Curriculum Chapter Ten Trialling a Sustainable Engineering Course

Chapter Two

2 Sustainability and Engineering Education

Introduction

The emergence of sustainability as the ultimate 21st century global challenge did not occur in a vacuum. Preceded by a formidable campaign which reached a crescendo in the 1990s, sustainability acknowledges the central role of education (Agenda 21 Rio Declaration, 1992). Efforts to introduce sustainability into higher education have been witnessed around the world (Allenby *et al.*, 2009). This chapter is a selective review of the literature on sustainability and sustainability education in engineering. It offers a concept clarification of sustainability and highlights the continuing efforts at teaching and learning about sustainability. Through the lens of three educational aims, namely *salvation, the state,* and *progress* (Aldrich, 2008), the chapter reviews sustainability education declarations and sustainability education construct. Thereafter, it critiques the derived construct providing an impetus for the appraisal of sustainability education in engineering. Sustainable engineering as a conceptual departure from conventional engineering practice alongside the principles, tools, and frameworks of the field are discussed. The chapter also highlights the application of sustainable engineering and the pedagogical approaches of sustainability education in engineering. The chapter ends with an overview of research in sustainable engineering education, stressing the need for more investigations in the developing world context.

Sustainability

Sustainability and sustainable development are used interchangeably in the present research. However, in some scholarly works sustainability is presented as the target of sustainable development. Consensus on this view is not yet attained. Since the landmark Brundtland Report in 1987 the word 'sustainable' has been taken up by academics, professional disciplines, non-governmental organisations, activists, policy makers and business organisations. The currency of sustainability in many fields of study reflects a deep concern for addressing the challenges of sustainable development. There is a subtle understanding that the challenge of sustainable development is the responsibility of all – an idea hinted in the main title of the Brundtland Report, *Our Common Future*. Contemporary sustainability discourse can be traced to centuries-long environmental concerns with the impacts of human civilisations.

Concern for the environment has manifested throughout history in a variety of ways, such as the seventh century legislation for protection of birds in Farne Islands in England and the mining law in Italy in 1556 (Stables and Keirl, 2015). Other historical manifestations of environmental concerns include Urban Sanitary Act of 1388 and Alkali Act of 1874 in England (Forbes, 1995). The Convention Relative to the Preservation of Fauna and Flora in their Natural State adopted in the 1930s by some African and European nations is another example of early environmental interests (Nash, 2005). Such moves to protect and conserve natural resources continued to emerge across time and place until the modern environmental movement emerged in the 1960s and 1970s (Lee, 1999).

The rise of environmentalism as a social, ethical and political movement is well-documented. Environmentalism is debatably the culmination of reactions to the alarmingly irresponsible exploitation of earth's natural resources since the Industrial Revolution. Use of pesticides in agriculture was noticed to be gradually killing insects causing starvation of birds, but also posing health risks to humans (Carson, 1962).This concern, which was highlighted by the scientist Rachel Carson (1907-1964) in her 1962 book *Silent Spring*, is agreed to be a watershed in the history of modern environmentalism. Events and discourses following the publication of *Silent Spring* continued to raise public awareness of the global threat posed by unmitigated use of natural resources. Environmental pressure groups emerged across the world forcing national and regional governments to take environmental concerns seriously.

The environmental movement gained great momentum with the inputs of such ‘neo-Malthusians’ as Paul Ehrlich and Garett Hardin (Bell, 2011). These scholars rekindled the controversial but famed Malthusian theory of population growth first developed by Thomas Robert Malthus (1766-1834) in eighteenth-century England. Malthus had predicted the imminence of famine and other social crises as a consequence of unchecked population growth, which he thought would surpass agricultural production (Robertson, 2012). Although Malthus’s prediction failed to materialise due to the mitigating impacts of agricultural technology such as mineral fertilisers that increased food production (Bell, 2011), the implications of overpopulation had been identified. Writing separately in 1968, Ehrlich and Hardin published *The Population Bomb* and *The Tragedy of the Commons* respectively. Central to these scholarly works is the interrelationship of human population, resource exploitation and the environment (Creech, 2012). These neo-Malthusians argued that negative environmental impact would continue unless population growth and resource exploitation were addressed.

In the 1970s, the environmental advocacy continued with the themes of overpopulation and resource consumption. The UN Conference on the Human Environment held in Stockholm in 1972 to further debate these issues. In the same year, the Club of Rome published *The Limits to Growth* which predicted serious consequences for untempered population and economic growth. The report proved controversial as the developing nations were enraged by the idea of halting economic growth, whilst the developed world was critical of the exclusion of technological solutions (Mills and Emmi, 2006). An important theme in the report was the critique of unlimited economic growth which formed the basis of the dominant development model. Physical and ecological limits to economic growth were acknowledged as inevitable (Bell, 2011). The report suggested a state of equilibrium or an economic system that attains “steady state before breaching these limits” (Bell, 2011, p.17) as a way out. This notion of a steady-state society or economy became part of the environmental discourse.

As environmental problems such as biodiversity loss, pollution, water shortages, and soil depletion became frequent, the debate on environmental protection continued to rage throughout the 1970s and 1980s. Human activities such as deforestation, land degradation, and direct exploitation were identified as likely responsible for species extinction and loss of biodiversity. In response to this problem, the United States enacted the Endangered Species Act in 1973, whilst the Convention on International Trade in Endangered Species of Flora and Fauna (CITES) came into effect in 1975 (Creech, 2012). Environmental pollution incidents such as the Amoco Cadiz oil spill (1978) and the Three Mile Island nuclear accident (1979) exemplified some of the consequences of resource exploitation. In 1984, a drought in Ethiopia left between 250,000 and one million people dead as a result of starvation (Kidane, 1989). These occurrences further bolstered the environmentalist position and served as rather tangible proofs of the impacts of unmitigated economic activities.

Amidst these activisms emerged evidence of climate change or global warming from rising temperatures (between 0.3 ºC - 0.6ºC) caused by human activities (IPCC, 1990). Carbon dioxide and other greenhouse gases were discovered to have been building up in the atmosphere. The build-up was attributed to the burning of fossil fuels and deforestation. Studies have shown that the atmospheric concentration of carbon dioxide increased from pre-industrial levels of 280 parts per million by volume (ppmv) to around 387 ppmv in 2008 (Bell, 2011). Climate change will have such direct impacts as extreme weather events (hurricanes, earthquakes, heat waves) and indirect effects (migration, reduced food and water security). A consequence of climate change that raises moral question is the likelihood that the people contributing least to the climate crisis will suffer most from its impacts (Costello, 2009). Thus, the threat of climate change reignited the debate on the incompatibility of environmental protection and economic growth, but also raised issues of social justice and equity.

In 1983, the UN convened the World Commission on Environment and Development (UNWCED) chaired by Dr Gro Harlem Brundtland, a former Norwegian prime minister. The Commission attempted to reconcile the seemingly opposing discourses of environmental protection and economic development. The outcome of UNWCED was not only the concept of sustainable development but also the term ‘sustainability’. The Commission echoed accumulated concerns of environmentalists over the years but also highlighted an intricacy: economic and social developments are inseparable from environmental issues (Brundtland, 1987). Consequently, the challenge facing the world was how to achieve a balance amongst environmental protection, social responsibility and economic viability. Sustainable development was presented as the only reasonable path towards the attainment of this complex trio.

The following definition of sustainable development was provided in the Brundtland Report: “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (Brundtland, 1987). This connotation has received wide acclaim as well as criticisms. Enthusiasts observe that the Brundtland definition was instrumental to creating a holistic view of the global sustainability challenge (Mebratu, 1998). Critics, on the other hand, argue that the definition is so vague that almost anything could be couched in sustainability terms. Regardless of these observations, the Brundtland definition has been the foundational groundwork for all discussions of sustainability and sustainable development. Three pillars of sustainability, namely economy, society and environment deduced from the definition are usually depicted by the diagram in Figure 2.1. The Venn diagram is the most common depiction of sustainable development, which features sustainability as the intersection of the three circles. Each of the three overlapping circles signifies a dimension of sustainability. The circles are perfect and of the same size to depict the equal importance of the three sustainability pillars. A situation in which only two circles overlap does not yield sustainability. Hence, the intersection of social and economic dimensions produces an equitable society, whilst that of economic and environmental components yields viability. Sustainability is achieved primarily by balancing the three pillars of economy, society and environment.

In furtherance of sustainability ideas, the UN instituted the Commission on Sustainable Development (UNCSD) following an Earth Summit at Rio de Janeiro in 1992. The Rio de Janeiro conference was not only acclaimed as the largest gathering of world leaders but as representing a turning point in the global efforts to address sustainability challenges. Some important UN conventions relating to biodiversity, climate change and desertification ensued from the summit (Bell, 2011). A crucial milestone following the summit was Agenda 21 which detailed pathways of sustainability implementation globally. Nations were expected to use the framework of Agenda 21 to come up with locally-relevant implementation strategies. The 1995 execution of Ken Saro-Wiwa, an environmental activist in the Niger-Delta region of Nigeria drew the attention of the international community to the intricate link amongst environmental justice, security, human rights and economic growth (Creech, 2012). Subsequent global sustainability conventions have repeatedly featured these issues. The interplay of environmental protection with social and economic issues as well as universal human rights has featured in the 2000 UN Millennium Development Goals, the 2002 World Summit on Sustainable Development and the UN 2030 Agenda for Sustainable Development.

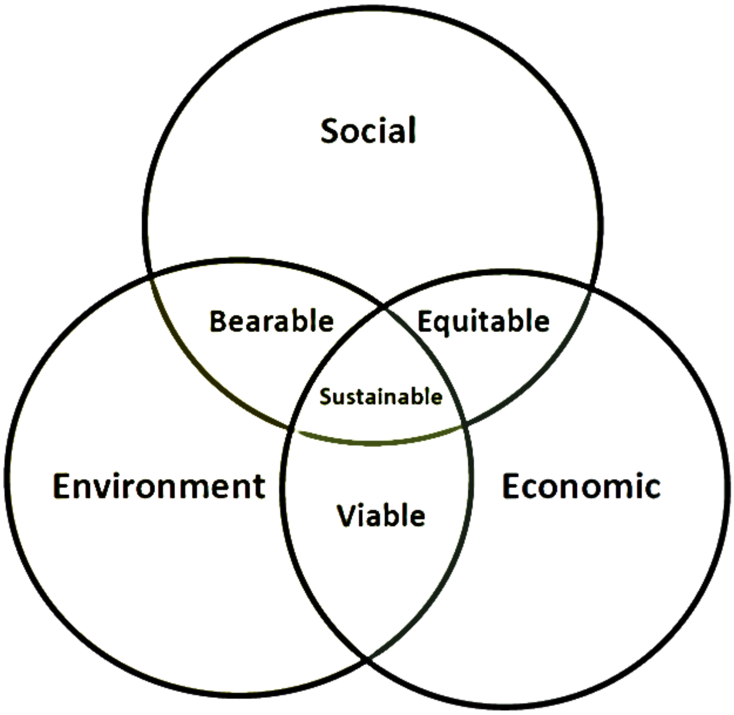

Figure 2.1. Pillars of sustainable development
Source: World Conservation Union, 2006

Sustainable development has important implications for the developing world. Given the exigencies of the socioeconomic needs in several developing countries, balancing the three dimensions of sustainability is quite challenging. Generally characterised by low human development, the countries in the developing world prioritise the fulfilment of societal needs. This, however, is not a recent phenomenon. Since the emergence of sustainability as a global agenda, the developing and the developed countries have held opposing views on the way forward (Giljum and Eisenmenger, 2004). The developing world has repeatedly invoked the idea of historical responsibility to argue that the developed world owes the rest of the world an ecological debt. Hence, the advanced countries should be more responsible for achieving sustainability than the developing countries, which are still struggling with multidimensional poverty, etc. These debates are not only continuing at international forums, but also reflected in government budgets. In Nigeria, for example, only a fraction of public resources (₦6 billion) is allocated to Sustainable Development Goals (SDGs) in the 2018 budget (FRN, 2018). By contrast, a large proportion of the budget (₦682 billion) is set aside for infrastructural and social development projects.

Educational Aims in Society

Human civilisation is historically replete with not only several scholastic achievements but also with the role of education in preserving humanity. Scholastic aspirations characterised Babylonian hieroglyphs[2], Athenian *grammata*[3], Spartan *agoge*[4], East Asia's Five Classics of Confucianism[5], and medieval Arabia's *Bayt al Hikmah*[6]. These wide-ranging didactic approaches devised by educators of diverse civilisational experiences have generally been aimed at salvation, statecraft, or material progress (Aldrich, 2008). Such multiformity of learning philosophies constitutes the milieu within which academic endeavours have continued. Sustainability education arose within this complex educational setting. Aldrich (2008) succinctly asserts that education as a significant branch of human history has been pursued *for salvation*, *for the state*, and *for progress*.

Education for Salvation

Education for salvation directs learning activity for the purpose of eschatological bliss. The longing for salvation is rooted in religion. An important message of religion in its various forms is the afterlife, which suggests another existence where ultimate justice will be dispensed. This teaching is central to the Abrahamic faiths of Christianity and Islam which further explain that salvation is for the righteous, whilst damnation awaits the malevolent. In the competing religions of Hinduism and Buddhism, salvation is presented as an escape from the endless cycle of rebirth to which the reprobate is bound. Similar salvation message is found in Zoroastrianism where *drujo demana* (house of lies) and *garo demana* (house of song) are reserved for the souls of evil and good people respectively (Contractor *et al*., 2016). Education for salvation guides

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[2] Hieroglyph: stylised picture of an object denoting a word, syllable, or sound in ancient Egyptian writing system.
[3] Grammata: Athenian school course comprising reading, writing and arithmetic exclusively taught to boys.
[4] Agoge: an education program aimed at acquisition of military skills and acumen including stealth, endurance and comradeship by Spartan males.
[5] Confucianism's Five Classics: a collection of five books, namely Book of Documents, Book of Odes, Book of Rites, Book of Changes, and Spring & Autumn Annals considered as main educational texts in imperial China.
[6]Bayt al Hikmah: The House of Wisdom was a centre of learning founded in medieval Baghdad on which scholars of all backgrounds and nationalities converged for purely academic purposes.

individuals towards deeds that will lead to peace and happiness in the afterlife. It is more or less a moralising educational framework with eternal bliss as the main aim.

Education for salvation is still relevant today as it continues to filter school curricula against ‘atheistic’ content in several countries. Steven Weinberg, the American physicist, in a BBC interview in 2003 recalled how science subjects were opposed in the Gulf States on the pretext that science was corrosive to religious beliefs (BBC, 2003). This could be an oversimplified representation of religious influence on education especially with the scientific progress made in the UAE, Saudi Arabia, and Iran. Nonetheless, the influence of education for salvation in many societies is undeniable. Therefore, the undiminished relevance of religious education must be acknowledged in sustainability education discourse. The qualities of education for salvation responsible for its unabated traction can be useful to a sustainability education framework. An appeal to religious values such as compassion, humility and self-discipline, which correspond to the social dimension of sustainability, could enhance the acceptability of sustainability education, especially in a deeply religious or communal society.

Education for the State

Education for the state guides learning towards citizenship and social cohesion. An arguably enduring scholastic aim, education for the state has continued to shape human intellectual affairs and lifestyles since the emergence of social organisations and the nation-states. The Spartan education model hallmarked by *agoge* is frequently referred to in the literature to illustrate an archetypal state-sponsored enculturation in ancient times (Knottnerus and Berry 2002). Education in Sparta was intended to imbue young men with valour and loyal patriotism in line with the Spartan triune ideal of uniformity, conformity and priority of collective interests (Hodkinson, 2002). An important reason adduced for the development of the Spartan education model was national survival. War, which the Prussian General Carl von Clausewitz (1780-1831) wittily describes as “continuation of politics by other means”, is a catalyst to education for the state goal (Howard and Paret, 1976). States whose territorial integrity, social stability or national interests are threatened have usually resorted to a state-centric education framework.

Patriotic orientation and influence in education have endured to-date. The modification of engineering education curricula during the Cold War to prioritise space engineering science is instructive. The rationale behind education for the state seems prima facie noble, however a deeper reflection on its actualisation exposes several downsides. The means of achieving education for the state involve selective reading of history and propaganda which are deleterious to the libertarian ideals of critical thinking and capacity for independent reasoning. Education for the state promotes a self-serving attitude albeit on a national scale akin to the motivation of the characters in the famed Tragedy of the Commons[7] scenario (Hardin, 2006). Such state-centric disposition has been blamed for the failed negotiations at various international conferences on climate change and other global matters. Consequently, education for the state could be inimical to global concerns including sustainability. Thus, the extent to which a society is guided by education for patriotism will inevitably determine its approach to a sustainability education.

Education for Progress

Education for progress stems from the ascendancy of reason as the determinant of human advancement both morally and materially. In contrast to the other two educational aims, education for progress seeks to develop a protean individual capable of critical thinking and independent reasoning. The Sophists circa 400BCE espoused an incipient form of such educational aim stimulating in young Greeks the desire for questioning and intellectual disputation (Sacks and Murray, 1995). Material advancement is an outcome of education for progress (Aldrich, 2008). Advancement made globally in healthcare, transportation, and communication amongst others is arguably due to a progress-focused education. Global citizenship which opposes uncritical allegiance to national, chauvinistic, religious, ethnic, or sectarian ideals is linked to education for progress (Golmohamad, 2009). Knowledge is understood as “justified true belief” which undermines narrow-mindedness and promotes an open-minded intellectual engagement.

[7] Tragedy of the Commons is a scenario-based explanation of the inescapable fate that awaits an egocentric and self-serving utilisation of the common good. Credited to the Englishman, William Forster Lloyd in 1832, the theory explains that individuals, driven by self-interest, will continually exploit a common resource until its usefulness is exceeded, resulting in a tragic end!

Education for progress has implications for sustainability knowledge. The valued goals of rational criticism and discerning autonomy can be underutilised resulting in morbid paranoia and conspiracy theories. Sustainability has, for instance, been criticised as a UN ploy to subjugate the world and micromanage the planet (Seabrook, 2002). A society with a critical mass of its population subscribing to such conspiratorial worldview could be impervious to sustainability education. Nonetheless, such strength of education for progress as critique of creed loyalty and dogmatism may well be the antidote to irrationality and paranoia. Additionally, the idea of global citizenship emphasised by education for progress could be tapped into to reinforce a sustainability education framework.

Implication for Nigeria

There are unmistakable traces of education for salvation, education for the state and education for progress in the Nigerian educational system including the engineering curriculum. Being an ethnically and religiously heterogeneous society, Nigeria enshrines secularism in its constitution (CFN, 1999). However, religion has remained a prominent feature of the Nigerian society. Given that Islam and Christianity are the dominant religions in Nigeria, *Islamic Religious Knowledge* and *Christian Religious Knowledge* are constant subjects in the syllabi of all Nigerian schools. Both subjects pervade the educational system from primary to tertiary levels. Also, most school-going children in Nigeria attend religious schools alongside the Western-style schools. The influence of these religious schools is quite significant. Characteristic of education for salvation, the religious instructions subordinate the learning activities of individuals, becoming a guiding framework for educational pursuits. The choice of whether to study engineering or medicine, for example, would be guided by a religious outlook. In some instances, the upshot has been antagonism of Western education as witnessed with the emergence of the terrorist group, *Boko Haram*, which literally means "Western education is a sin". Hence, even though it is not an official educational aim in Nigeria, education for salvation is manifestly consequential.

With respect to education for the state and education for progress, there seems to be an official position in favour of both approaches. Nigeria's National Policy on Education is premised on the concept of education as an instrument for national development (FME, 2013). The ideals of progress and patriotism are encapsulated in the Nigerian educational philosophy. One of the objectives of education enumerated in the national policy is the development of a morally sound and patriotic citizen. There is also the goal of promoting education for skill acquisition, poverty reduction, and information technology capability at all levels (FME, 2013, 2016). The extent to which the populace is aware of these underlying philosophies is indeterminable. Nevertheless, being the undergirding principles of the Nigerian educational system, the philosophies inevitably guide individuals' educational pursuits. The National Policy on Education informs the standard, structure, strategy, and management of education in Nigeria. With features of education for the state and education for progress officially recognised within it, the educational system in Nigeria has important implications for sustainability education.

Whilst education for salvation is not acknowledged as an explicit government policy, education for the state and education for progress are featured in official documents. Nonetheless, the potential influence of the three educational aims could be equally significant. Therefore, the presence of these educational approaches in Nigeria implies that sustainability education interventions could utilise their various strengths to attain success. For instance, an intervention could proceed by determining the most relevant of the three educational aims to a region. The justification for the intervention could then be aligned with the identified educational approach.

Evolution of Sustainability Education

The role of education as an essential instrument for inculcating sustainability ideals in the global citizenry was identified during the Earth Summit in Rio de Janeiro in 1992. The report of the Summit, Agenda 21, declared education as "critical for promoting sustainable development and improving the capacity of people to address environment and development issues" (UN-Rio Declaration, 1992). This declaration simply echoed the long-established understanding of education as a vehicle for social reform and change. In the history of human civilisation, education has been responsible for not only numerous accomplishments, but arguably for the survival of the human race. Calls for sustainability education were based on the need to enable global change for the prosperity of present and future generations.

An important cue from the three educational goals highlighted above is the way a presumed philosophical worldview guides the evolution, direction and deployment of an educational system. Indeed, a society's anthropological[8], teleological[9], axiological[10], cosmological[11], and metaphysical[12] stance greatly influences the type of education it countenances. The sustainability debates peaked in the 1990s with the declaration of education as absolutely and evidently consequential for sustainable development. With the benefit of hindsight from human civilisational experiences, education in its metanarrative form was suggested as an undisputed enabler of sustainability. Since sustainability crises were anthropogenically induced, it was reasoned that humans' teleological, axiological and anthropological outlooks needed to change globally.

Additionally, the need to reconsider the increasingly consumerist, materialistic and unsustainable lifestyles of modern societies was exigent. Paradigms inherent in the three educational aims may have encouraged individuals into the unsustainable lifestyles aggravating contemporary sustainability challenges. Evidence of this connection subsists partly in the global population educated over the years within the three educational contexts vis-à-vis the heightened challenges. The question of an educational system's focus and its relationship with sustainability then becomes relevant; hence the need to reorient education for sustainability. These thoughts formed part of the discourse of education for sustainable development which had by the late 1990s become a fixed agenda item for several international meetings and conferences.

Sustainability Education Declarations

Starting in 1990 with Talloires Declaration, the international community successively issued such other declarations on sustainability education as Halifax Declaration in 1991, Agenda 21 in 1992, and Kyoto and Swansea Declarations in 1993 (Phuong, 2013). Luneburg Declaration in 2001, Ubuntu Declaration and UNDESD (2005-2014) in 2002 further reinforced international efforts towards an education for sustainability. Within the declared UNDESD several declarations also ensued, such as Graz Declaration in 2005, Sapporo Sustainability Declaration in 2008, World Conference on

[8] Anthropology: beliefs about the nature and purpose of humans in general and, oneself in particular.
[9] Teleology: beliefs about the meaning and purpose of the universe and the interrelations of its inhabitants.
[10] Axiology: beliefs about the nature of value; good and bad; and right and wrong.
[11] Cosmology: beliefs about the nature of the origins of the universe and life.
[12] Metaphysics: beliefs about the ultimate nature of reality.

Higher Education for Sustainability as well as Turin and Abuja Declarations in 2009. The People's Treaty on Sustainability for Higher Education (Rio+20) in 2012 was trailed by the recent UN 2030 Agenda for Sustainable Development. A common theme intrinsic to all the proclamations is the dominant role of education, especially higher education, to the realisation of sustainability objectives.

Talloires Declaration

Concerned about aggravating sustainability challenges, some university leaders converged in the French commune of Talloires in the autumn of 1990 to promote sustainability in higher education. The Talloires Declaration resulted from this international conference (Shriberg and Tallent, 1990). Talloires Declaration is a 10-point strategy informed by the fact that universities 'educate most of the people who manage society's institutions', and therefore have a responsibility to produce environmentally literate and sustainability conscious citizens (Hill *et al.*, 2001). Issues of unsustainable production and consumption patterns, inadequate expertise in environment-related discipline as well as incredulity of professionals about their field's imprint on the environment were deliberated at the conference. In strategising to address these challenges, the Declaration stressed the need for multidisciplinary structures and environment-related programmes. Thirty-one representatives from 15 nations cutting across both developing and developed countries signed the Talloires Declaration. The Association of University Leaders for a Sustainable Future (ULSF) was formed from the conference to serve as the secretariat of these signatories. ULSF's recent record indicates that some 430 universities in over 40 countries across the world have endorsed the Talloires Declaration (ULSF, 2016).

Halifax Declaration

The Halifax Declaration was issued in December of 1991 following a meeting of 33 university representatives from 10 countries across 5 continents (Wright, 2007). The conference which held at Halifax, Canada was jointly sponsored by the International Association of Universities (IAU), United Nations University (UNU), Association of Universities and Colleges Canada, and the Canadian Dalhousie University (IAU, 2004). Inspired by the Talloires Declaration and the anticipated United Nations Conference on Environment and Development (UNCED), the Halifax meeting intended to gauge universities' role and contribution towards sustainable development (Wright, 2007). The Halifax meeting justified its convening on increased anthropogenic activity and on the need to tackle poverty. The meeting acknowledged intellectual resources and mutual vulnerability of both developing and developed nations as vital for sustainability discourse. Contending that universities exist for improving the social and economic conditions of people, the Halifax conference stressed the role of education in public awareness, teaching and practising sustainability ideals. Halifax Declaration differed from Talloires Declaration in not requiring any formal ratification by participating countries. Nonetheless, its 6-point action plan invited the dedication of all universities to rise to the occasion of fostering a sustainable future.

Agenda 21

Agenda 21 is an outcome of UNCED held in the Brazilian city of Rio de Janeiro in 1992. The Rio Earth Summit, as the conference is alternatively called, assembled around 178 UN Member States to devise a comprehensive strategy for promoting sustainable development worldwide. UNCED issued a 350-page document dubbed Agenda 21 or "Agenda for 21st Century", which is a 40-chaptered text detailing programme of action in various environmental and developmental sectors. Reiterating concerns about limited resources and primacy of poverty eradication, Agenda 21 highlighted actions that should be taken in several sectors of the society. Chapter 36 of Agenda 21 captioned '*Promoting Education, Public Awareness and Training*' specifically called for the reorientation of education towards sustainable development (Agenda 21, 1992). The metanarrative of education featuring formal, informal and non-formal means was promoted. Attitudinal change and capacity to participate in addressing sustainability concerns were inextricably tied to the education of people. Also significant in the recommendations of Agenda 21 was for educational authorities to undertake an exhaustive review of curricula to reflect the multidisciplinarity of tackling sustainability challenges. Ironically, Agenda 21 is a favourite subject of conspiracy theorists who claim that the treaty promotes "world government" and deep socialism.

Kyoto Declaration

The Kyoto Declaration of 1993 resulted from the 9th IAU Round Table which held in Kyoto, Japan and was adopted by 90 international university leaders. Seven key reasons for its espousal included the international dimension of sustainable development and ethical duty of present generation. Others were the need for a deepened grasp of sustainable development, prevalent global socio-economic disparities, and intellectual capacity of universities to facilitate change. Further rationalising its uptake on the necessity of cooperation amongst all stakeholders and on IAU to take the lead, the Kyoto Declaration recommended a 10-point action plan for universities. Central to this plan is for individual HEIs to promote the principle and practice of sustainable development amongst both staff and students irrespective of field of study. The Kyoto Declaration specifically recommended universities to employ their intellectual resources in developing interdisciplinary and collaborative research programmes for sustainable development. An important caveat highlighted by the Kyoto Declaration, however, was that the interpretation of sustainable development must not proceed in such a way as to cause ‘sustained undevelopment for certain systems’ (IAU, 1993). Accordingly, the need to engender requisite international consciousness, worldwide sense of responsibility and purposefulness was reiterated. In August of 2000 in South Africa, Kyoto Declaration was officially ratified by over 650 institutions who were IAU members (Blackburn, 2007).

Swansea Declaration

Events at Talloires and Halifax inspired the Swansea Declaration issued by the Association of Commonwealth Universities (ACU) in 1993. Impelled by the need to counter the poor representation of universities at the 1992 UNCED, ACU decided, at its 15th Quinquennial Conference in Swansea, to reinforce worldwide calls to action on sustainable development. The Swansea Declaration justified its issuance on such concerns as expressed by previous declarations including widespread environmental degradation and endemic poverty. The Declaration underscored the import of equality amongst nations in achieving sustainable development through a 7-point action plan. Swansea Declaration reemphasised HEIs’ roles of disseminating better understanding of sustainable development, providing moral and ethical lessons, and guiding environmental literacy. Universities were called on to contribute more effectively to the attitudinal and policy changes required for a sustainable future. An important emphasis of the Swansea Declaration was the need for universities in more developed countries to support sustainable development education initiatives in less fortunate universities. The Swansea Declaration was affirmed by representatives from over 400 universities in 47 countries around the world (Blackburn, 2008).

Luneburg Declaration

The Global Higher Education for Sustainability Partnership (GHESP) formed by COPERNICUS[13], IAU, ULSF and UNESCO issued the Luneburg Declaration in 2001 at the end of a conference themed "Higher Education for Sustainability: Towards the World Summit on Sustainable Development 2002" (Barth, 2015). The Declaration emerged in order to present a common position on higher education for sustainability at the forthcoming 2002 World Summit on Sustainable Development in Johannesburg. Luneburg Declaration was aimed at ensuring that the import of higher education was aptly captured in the international framework that would follow the Rio+10 Summit. The Declaration reflected commitments to Chapter 36 of Agenda 21, and the Talloires and Kyoto declarations amongst other international pacts. HEIs were specifically called to perform 9 actions including continual pedagogical review and updating vis-à-vis sustainability research, prioritising sustainability education, promotion and implementation of sustainability projects, and focus on closer stakeholder interaction for sustainability issues. Luneburg Declaration is unique in its call for the production of a "tool-kit" to facilitate concrete actions by universities in recognition of the implementation challenges encountered by previous declarations (Wright, 2007). The Luneburg Declaration did not require new signatories as previous declarations were endorsed.

Ubuntu Declaration

The Ubuntu Declaration is a product of the joint session between GHESP partners and representatives of some international scientific associations at the Johannesburg World Summit in 2002. Convinced that time was ripe for the mainstreaming of sustainability knowledge into educational systems globally, participants at this meeting

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[13] **CO**-operation **P**rogramme in **E**urope for **R**esearch on **N**ature and **I**ndustry through **C**oordinated **U**niversity **S**tudies.

deliberated on a variety of modalities. The problem of sustainable development was carefully couched as contingent on the effective application of science and technology. Furthermore, concern was expressed about the failure of the international community to maximise the potential of education as a vehicle for achieving sustainable development. The *Ubuntu Declaration on Education and Science and Technology for Sustainable Development*, as the unabridged title of the declaration reads, endorsed and reaffirmed Earth Charter principles, Chapter 36 of Agenda 21 and the Luneburg Declaration. The hallmark of the Ubuntu Declaration is its emphasis on 3 significant points: need for greater global focus on education, essential role of education in the application of science and technology for sustainability, and the importance of partnerships (WSSD, 2002). The Ubuntu Declaration concluded with an explicit recommendation for sustainability knowledge to permeate all educational levels – primary to tertiary – and to integrate various means of education – formal, non-formal and informal.

UN Decade of Education for Sustainable Development

The United Nations General Assembly (UNGA) in December 2002 adopted Resolution 57/254 approving the period 2005-2014 as the Decade of Education for Sustainable Development (UNDESD). UNESCO was designated as the lead agency to coordinate international efforts towards promoting and implementing the Decade. The launch of UNDESD was conceived at the WSSD Preparatory Committee IV (UNESCO, 2006). It was thought that a UN declaration on ESD would galvanise Member States to not only implement extant sustainability pacts but also conceive new ESD initiatives. The idea was for education to induce behavioural changes that will guarantee environmental integrity, economic viability and a just society. Educational resources around the world would be mobilised to equip global citizenry with the requisite skills and knowledge to live sustainably. UNGA stated UNDESD's goal as "encouraging Governments to consider the inclusion…of measures to implement the Decade in their respective education system" (UNGA, 2002). Four UNDESD focus areas were promoting and improving quality education, reorienting educational programme, building public understanding, and providing practical training (UNESCO 2005). In "*Shaping the Future We Want*", UNDESD *Final Report*, the establishment of ESD policies around the world, education curricula reorientation, and deployment of new approaches to ESD were presented as achievements. However, leadership, conducive organisational climate and evidence grounding of educational reorientation requirement had been marginally successful (UNESCO, 2014).

Graz Declaration

Coincident with the inauguration of UNDESD, the Graz Declaration was issued in 2005 in the Austrian city of Graz (UNESCO, 2005a). The Declaration followed a joint meeting of COPERNICUS, the Karl-Franzens-University Graz, the Technical University Graz, Oikos International and UNESCO. It was another global effort committing universities to sustainable development and emphasising sustainability opportunities for European Higher Education in particular and other regional universities in general. Drawing on insights from past conferences on sustainability, the Graz conference discussed the role of HEIs in societal transition towards sustainable development. The Conference concluded that UNDESD presented a formidable challenge to HEIs worldwide. EU ministers of education were encouraged to model the social dimension of European higher education on a sustainable development framework. The moral obligation of HEIs in producing responsible professionals and future leaders in society and economy was emphasised (Filho *et al.*, 2007). To meet sustainability education objectives, the Graz Declaration called on firstly, universities to place sustainability at the core of their activities and plans. Secondly, EU education ministers were requested to pursue the integration of sustainable development issues into the Bologna Process. Finally, UNESCO was entreated to support the Graz Declaration and promote international cooperation amongst universities globally (Grindsted, 2011).

Sapporo Sustainability Declaration

Sapporo Sustainability Declaration resulted from a 2008 meeting of 27 delegates of educational and research institutions in G8 member nations with representatives from UNU and 7 major universities in non-G8 member states (UNESCO, 2014). Emerging from the 3-day University Summit, the presidents of the attending universities endorsed the Sapporo Declaration calling on HEIs globally to follow suit. The Declaration refreshed global attention on the indispensable role of universities in sustainability and detailed specific actions to be undertaken. In a section captioned *"Joint Affirmations and Actions for Sustainability*", the Declaration listed 8 principles underpinning the sustainability role of universities (SSD, 2008). These included the importance of sustainability in the 21st century, political expediency of sustainability concerns, and neutrality and objectivity of universities necessary to inform social and political change. Others were the need to restructure scientific knowledge, exigency of a network of networks, need for knowledge innovation, and the function of the university campus as an experimental model. Affirming these principles, participants declared to strive towards the fulfilment of global sustainability through diverse action programmes. Priority was given to cooperation and joint research efforts aimed at providing support to educational institutions in both developed and developing nations (Beaudreau, 2001).

Turin Declaration

Turin Declaration ensued from a 2009 G8 University Summit preceding the ‘L’Aquila 2009 G8 Summit’ (G8Summit, 2009). The Declaration consolidated on the success of Sapporo Declaration. Participants at the G8 University Summit represented a diversity of culture which enriched deliberations and resulted in a robust declaration. The understanding of sustainable development as an important challenge of the 21st century evident in the complex interdependence of economics, ethics, energy policy and ecology (so-called 4E’s) was affirmed. Several agreements were reached at the Summit including the implementation of new social and economic development models congruent with sustainability ideals (Sylvestre *et al*., 2013). A significant decision in the Turin Declaration was for HEIs to facilitate access to high quality sustainability education for the benefit of policy makers. Also agreed were the implementation of sustainable development education programmes, sustainable and responsible research prioritisation, and engaging students in policy and decision making. Furthermore, attendees at the Turin Conference undertook to advance sustainable development through partnerships with both private and non-profit actors. One of the strengths of the Turin Declaration was its call for a holistic thinking and an integrated approach to addressing the issue of sustainability in higher education.

2009 World Conference on Higher Education

The 2009 World Conference on Higher Education (WCHE) was held between 5 and 8 July 2009 at the UNESCO Headquarters in Paris (UNESCO, 2010). It was an international gathering driven by the desire to assess emerging developments in higher education since the late 1990s. With a record figure of 1400 participants from over 150 countries in attendance, the 2009 WCHE embodied a diversity of opinions and vested interests (UNESCO, 2010) . The Conference discussed an array of global challenges stressing the role of higher education in addressing them. Guided by internationalisation and globalisation theories amongst others, participants emphasised the need for all stakeholders to identify innovative ideas that would facilitate quality higher education globally. A holistic perspective of educational system defined by nonlinearity and interconnectedness was recognised as invaluable to the provision of quality education. In a series of plenary sessions, the Conference covered such focus areas as increased demand, social responsibility, governmental role, integration and harmonisation, as well as excellence in African higher education. An important recommendation of the 2009 WCHE was the call to replace the conventional one-way knowledge “transfer” model (usually from developed to developing nations) with a cross-boundary sharing framework featuring endogenous knowledge. The prime issue of sustainable development permeated the entire deliberations of the Conference with sustainability acknowledged as some kind of paradigm for change.

Abuja Declaration

In the Nigerian capital of Abuja in 2009, the Association of African Universities (AAU) convened its 12th General Conference from which emerged the Abuja Declaration (AAU, 2009). The Declaration focused on the role of higher education in sustainable development in Africa. Beginning with a series of acknowledgements including an applicable sustainable development definition, globalisation impact, Africa’s sustainability peculiarities and higher education’s potential, the Declaration called for action from such stakeholders as HEIs, national governments, regional organisations, and development partners. Similar to a number of previous declarations, the Abuja Declaration singled out higher education for special charge in scholarly and scientific research necessary for a sustainable future. The conservative tendency of African HEIs to engage in research devoid of local developmental content and needs was highlighted. HEIs were called to reengineer education systems for sustainability, which would ensure transdisciplinary teaching and synergy among regional institutions. National governments were requested to guide educational curricula towards sustainability with emphasis on spirituality, ethics and morality (Shallcross and

Robinson, 2007). The Abuja Declaration was a significant proclamation on sustainability which provided the much needed African context to the discourse of sustainability in higher education.

The People's Sustainability Treaty on Higher Education

The People's Sustainability Treaty on Higher Education also called Rio+20 Treaty was developed in May 2012 in a bid to further international efforts at rethinking HEIs' role in the transition towards a sustainable society (COPERNICUS, 2013). Over 30 stakeholders including government agencies and student associations were involved in drafting the Treaty. The Rio+20 Treaty proved unique as it proceeded on the premise of education sector transformation. An argument is made in the Treaty about the need for higher education to transform itself before it can meaningfully contribute to sustainable development. Blame is laid on HEIs for the unsustainable lifestyles that result from its dominant education paradigm. HEIs are said to require change in knowledge structure, promotion of intercultural understanding, effective leadership and use of ICT. Based on a number of principles including efforts alignment, partnership, sustainability as a learning process, and access to the underprivileged, the Rio+20 Treaty declared to effect change at 5 levels. These involve 'cultural change' underpinned by institutional and HEIs stakeholders and 'campus management' for sustainability to showcase biodiversity conservation, environmental management systems and low carbon footprint. The next proposed level of change is curricular, which seeks to reorient education towards sustainable development. Another level of change is 'community engagement' aimed at revitalising the communal responsibility of HEIs (UN, 2012).

UN 2030 Agenda for Sustainable Development

The UN 2030 Agenda for Sustainable Development was adopted by UNGA at the 70th anniversary of the UN in New York in 2015 (UNGA, 2015). It is a global call to pursue some 17 Sustainable Development Goals (SDGs) and 169 targets. Informed by decades of worldwide sustainability polemics with variously proposed sustainability-oriented strategies, the UN 2030 Agenda is an ambitious framework for global transformation. The Agenda is poised to successfully stimulate action across the world in "areas of critical importance for humanity and the planet" (UNGA, 2015). Various goals including poverty eradication, gender equality, sustainable consumption and production patterns, and revitalised Global Partnership for Sustainable Development feature in the Agenda. The preamble of the UN Resolution which details the 2030 Agenda hinges SDGs on the complex interrelationship of the so-called 5 P's: people, planet, prosperity, peace and partnership. The UN 2030 Agenda highlights current unsustainable state-of-affairs stressing imminent risk to people and planet. The Agenda's congruency with the Universal Declaration of Human Rights, the Millennium Declaration and the Declaration on the Right to Development is underscored. SDG 4 stresses the need for inclusive and equitable quality education as well as lifelong learning opportunities for all. This fourth objective covers ESD over the next 15 years.

Table 2.1. Summary of sustainability education declarations

Year	Declaration	Scope	Description	Emergent Theme
(a)	(b)	(c)	(d)	(e)
1990	Talloires Declaration	Global	First global declaration on environmental sustainability education initiating involvement of HEIs in enabling sustainability	Moral obligation; Environmental literacy; Environmental sustainability
1991	Halifax Declaration	Global	Declaration of 33 university leaders from 10 countries across 5 continents who were motivated by the need to complement Talloires and to prepare for anticipated UNCED 1992	Moral obligation; Ecological literacy; Socioeconomic sustainability; Partnership with NGOs; Public outreach; Interuniversity cooperation
1992	Agenda 21	Global	Outcome of UNCED 1992 in which Chapter 36 of the Agenda entitled '*Promoting Education, Public Awareness and Training*' called for reorienting education towards sustainable development	Moral responsibility; Education metanarrative; Ecological literacy; Partnerships; Sustainable research Multidisciplinary curricular review
1993	Kyoto Declaration	Global	IAU declaration with over 650 signatory institutions seeking to consolidate HEIs role in sustainable development but cautioning against 'sustained undevelopment'	Moral obligation; Sustainability literacy; Sustainable physical operations; Interuniversity cooperation; Public outreach; Curricular change

(a)	(b)	(c)	(d)	(e)
1993	Swansea Declaration	Global	Issued by ACU in protestation of poor HEIs presence at UNCED 1992 and in complementation of Talloires and Halifax seeks to reinforce worldwide calls to sustainability actions	Moral obligation; Sustainability literacy; Public outreach; Partnerships; Sustainable research; Interuniversity cooperation
2001	Luneburg Declaration	Global	A GHESP declaration on SHE in anticipation of 2002 WSSD aimed at ensuring that the indispensable role of HEIs in sustainability was captured in the international framework	Public outreach; Sustainable research; Curricular change; Partnerships; Interuniversity cooperation; Moral obligation
2002	Ubuntu Declaration	Global	Result of a joint session between GHESP and representatives of some international scientific associations such as WFEO and AAS in which application of science and technology was stressed	Moral obligation; Public outreach; Technocentrism; Sustainable research; Interuniversity cooperation; Partnerships; Curricular change
2002	UNDESD	Global	Period 2005-2014 set aside by UN through Resolution 57/254 to galvanise global support for the orientation of education towards sustainability	Sustainability literacy; Public outreach; Curricular change; Sustainability models; Monitoring mechanisms; Differentiated responsibility
2005	Graz Declaration	Regional (Europe)	Coincident with UNDESD and issued from a joint meeting of COPERNICUS, Karl-Franzens, Oikos, and UNESCO which emphasised sustainability opportunities for European higher education	Moral obligation; Sustainability literacy; Public outreach; Interuniversity cooperation; Curricular change; Sustainability models; Partnerships

(a)	(b)	(c)	(d)	(e)
2008	Sapporo Declaration	Global	Consequence of G8 member nations meeting with 7 non-G8 universities and UNU in which global attention to sustainability was refreshed and re-invigorated	Sustainability literacy; Political expediency; Moral obligation; Curricular change; Sustainability models; Interuniversity cooperation
2009	Turin Declaration	Global	Ensued from G8 University Summit consolidating on Sapporo to acknowledge HEIs' critical role in availing policy-makers with high quality sustainability education	Sustainable research; Partnerships; Holism; Sustainability model
2009	WCHE	Global	An international gathering of UN Member States aimed at assessing progress of sustainability in higher education over the years which witnessed a record participation of 1400 attendees	Holism; Lifelong learning; Moral obligation; Top-down approach; Endogenous knowledge; Sustainability paradigm
2009	Abuja Declaration	Regional (Africa)	Arguably first African declaration on sustainability education organised by AAU which provided the much needed developing world context to sustainability education discourse	Sustainability contexts; Sustainability literacy; Partnerships; Sustainable research; Curricular change; Interuniversity cooperation; Top-down approach
2012	Rio+20 Treaty	Global	Developed by over 30 HEI stakeholders to further international efforts stressing the need for transforming the education sector	Education transformation; Top-down approach; Partnerships; Lifelong learning; Sustainability models; Curricular change
2015	UN 2030 Agenda	Global	A global agenda by UN to pursue 17 SDGs and 169 targets informed by decades-long sustainability debates in which SDG 4 emphasises the need for education	Lifelong learning; Equity; Holism; Partnerships

Critique of Sustainability Education Declarations

Several points of interest occur in all attempts at a comparative review of the various sustainability education declarations. The declarations lend themselves to a range of discursive approaches including thematic consideration, temporal trend study, and discourse and content analyses. Following the issuance of over 10 sustainability education declarations by the late 1990s, studies on their thematic content emerged. A thematic analysis of the declarations appeared in Wright (2002) which identified eight themes from a scrutiny of seven sustainability education declarations. Themes such as moral obligation, sustainability models, sustainable research and public outreach were observed. Others were interuniversity cooperation, partnership with governments/industry/NGOs, interdisciplinary curriculum development and ecological literacy (Wright, 2002). These themes became embedded in subsequent sustainability education declarations at varying degrees of importance. However, the more recent declarations were enriched with more principles as sustainability education debates improved over the years. Table 2.1 summarises the education declarations highlighted in the preceding sections and features Wright's (2002) identified themes as well as emerging motifs from succeeding declarations.

The shifting emphases in the sustainability education declarations are indicative of the evolutionary character of sustainability both as a concept and as an educational movement. The incipient declarations, for example, emphasised environmental or ecological literacy, whilst the later declarations stressed sustainability knowledge. This is a non-trivial point as sustainability education differs from environmental education. The Brundtland Report had in 1987 expressed sustainability as a balance among economy, environment, and society (Brundtland, 1987). Environmental education is, therefore, a subset of sustainability literacy. Nonetheless, environmental education continued to be somehow equated to sustainability literacy post Brundtland Commission as the early declarations show. The drawback of such conflation is the inadvertent disregard of the other two important sustainability dimensions. The change in emphasis from environmental knowledge to sustainability literacy in the Kyoto Declaration in 1993 is a recognition of the need to rectify this inaccuracy. However, it could also represent a watering down of the ecological elements of sustainability in favour of the less challenging emphasis on economics and social development.

Notwithstanding this possibility, it is apposite to infer that sustainability education declarations are evolutionary and adaptive.

Another interesting observation from the sustainability education declarations is the use of concepts such as holism, top-down approach and technocentrism. Holism is a principle espoused in systems thinking to manage complexity. Although sustainability has always been understood as a complex problem, proposal of systemic solutions in ESD is not accelerated. The adoption of systems thinking principles in sustainability education declarations initiated by the Turin Declaration paralleled an ascendancy of systems science ideals in the intellectual community. Similarly, the suggestion of top-down approach in some of the declarations to emphasise the critical role of national governments and policy-makers in sustainability education is not acausal. Declarations that preceded the 2009 WCHE, which stressed the top-down approach, were noticed to have been minimally implemented globally due to a lack of political will. The emphasis of a top-down approach in sustainability education is, therefore, to stimulate governmental action worldwide. In the same vein, the consideration of technocentrism which promotes the centrality of science and technology in addressing contemporary challenges indicates technophiles joining the sustainability education debate. Hence, sustainability worldview, which guides the sustainability education declarations, could be inferred as basically open and eclectic.

Conspiracy of silence is another point of interest in the declarations. There seems to be no reference in the declarations to the role played by universities and HEIs in the current unsustainable lifestyle characterised by inordinate consumerism. The declarations readily construct the university as an enabler and possessor of the remedy to sustainability challenges. However, there is no gainsaying that the seeds of sustainability crisis flourished within the HEIs from which several global leaders graduated. The contribution of the intellectual community in what Sterling (2001) aptly describes as 'sustaining unsustainability' is undeniable (Sterling, 2001). An endless list of unsustainable outcomes could be drawn from the activities of HEIs including the atomic bomb, fossil fuels and so on. Nevertheless, university education is undoubtedly key to social reform and transformation as already discussed. However, HEIs as currently structured may be handicapped for a meaningful ESD. The prevailing educational paradigms with their contextual shapers need to be re-examined and failure of the declarations to acknowledge this fact is worrying. Reflexivity is an important step towards bringing about positive change like the one being suggested by the sustainability education declarations. Consequently, arguing for an ESD without acknowledging the emancipatory and instrumentalist functions of education as implied in the overarching educational aims leads to a potentially problematic construct.

Sustainability Education Construct

From the declarations a sustainability education construct is apparent. Sustainability education is variously referred to as education for sustainable development (ESD), sustainable education (SE), education for sustainability (EfS) and recently sustainable higher education (SHE). These terms are used interchangeably on the premise of education as a solution to sustainability challenges. Sustainability education is about reorienting education towards sustainable development, which emphasises 'values of justice, equity, tolerance, sufficiency and responsibility' (UNESCO, 2009). In the sustainability education construct education about and for sustainability will be taught to students in HEIs, although lifelong learning seeks to stretch this beyond formal education. Sustainability education is context-dependent espousing the principle of common but differentiated responsibility. This means individual HEIs can use the construct as a model to develop a sustainability education framework consistent with local circumstances. Additionally, sustainability education through the top-down approach recognises the role of accreditation bodies and policymakers in incentivising relevant management. Furthermore, sustainability education is constructed as an essentially multidisciplinary and interdisciplinary endeavour. Therefore, it is fashioned into a framework that is imprecise, dynamic, eclectic, open, adaptive and evolutionary.

The laudable efforts at implementing sustainability education are still ongoing with new initiatives developed globally. Nonetheless, the extant education paradigm which has been accused of 'sustaining unsustainability' has remained somewhat inviolate. The question worth asking is how a system with such reputation can be trusted to reorient 'itself' towards sustainability. There is already an inherent misalignment in the sustainability education construct which readily presents hiccups at the point of implementation. Compromises are often made based on arguments from pragmatism and in the process sustainability robustness is lost. This perhaps accounts for the minimal successes recorded on the global march towards sustainable development. In spite of the upsurge in sustainability education programmes in the last two decades, NASA data indicate that 2015 was the hottest year on record (NASA, 2016). In Nigeria, environmental and socioeconomic problems have increasingly manifested in several parts of the country. The south-eastern city of Port-Harcourt has been intermittently covered in soot, which government officials have attributed to illegal refining of crude oil (Warami, 2017). Improvised oil refining is a widespread practice in the oil-rich Niger-Delta which does not only pose environmental health hazards, but also economic cost. Unsustainable agricultural practices such as excessive livestock farming and felling of trees occur frequently in northern Nigeria (Ohunakin *et al.*, 2014).

The fact that more sustainability education has not yielded positive sustainable behaviour in the global citizenry points to a fundamental discordancy in its construct. The existing educational paradigm is by default unsustainable and guided conjointly by *education for salvation, education for the state* and *education for progress*. The relentless consumerism of the 21st century might not be unconnected with a potent desire for material acquisition promoted by the education for progress paradigm. Also it is not inconsequential the increasing number of people who subscribe to conspiracy theories about sustainability issues. Referencing academics from reputable HEIs such as the MIT Professor of Meteorology, Richard Lindzen[14], conspiracy theorists have occasionally achieved some success misinforming the public. It is therefore contended that sustainability education as currently framed juxtaposes myriad subtleties to take on a crisis for which it is ill-equipped. An enhanced structure will be the one in which sustainability worldview guides human societies, which in turn direct the development and deployment of sustainability education as illustrated in Figure 2.2.

From the pragmatic perspective, a focus on achieving sustainability worldview globally is not only naïve but also futile. Whilst not undermining the pragmatist efforts that have produced an assortment of sustainability courses in HEIs, it is noteworthy that a sustainability worldview is feasible. In line with Einstein's clichéd assertion that 'no problem can be solved from the same consciousness that created it,' priority should be given to changing those aspects of our social values that are incompatible with sustainability.

[14] Richard Lindzen is an American Professor of Meteorology at MIT who has been critical of IPCC claims about climate change stating that the Earth had just emerged from the "Little Ice Age" in the 19th century which is expectedly followed by warming.

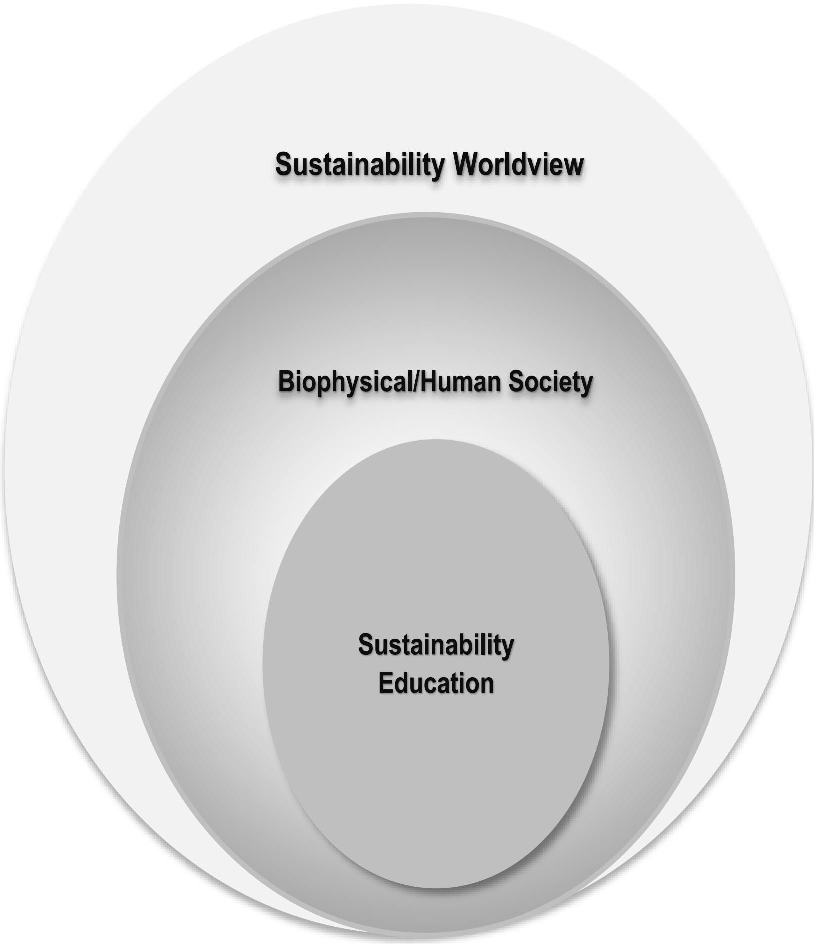


Figure 2.2. ESD as an outcome of sustainability worldview
Adapted from Sterling (2001)

Accordingly, the definition and understanding of both successful life and accomplished person will have to change. Another downside of the extant sustainability education construct is that it leads to cherry-picking of sustainability ideals. In the Western world, for example, the environmental dimension of sustainability is so stressed that the mention of sustainability instinctively evokes a need for the exclusive protection of the Earth (Allenby *et al.*, 2009). The social aspects of sustainability tend to be underemphasised especially in the US as they are in direct conflict with the American libertarian sense of individualism. Social sustainability also connotes sharing and in many Western societies '*there is no such thing as a free lunch'*. Unless a sustainability worldview is attained, sustainability education as currently conceived can only go so far.

Sustainable Engineering and Education

Engineering is intricately connected with the complex problems of sustainability, owing to its role of satisfying human needs and aspirations. Going forward into the future, engineering is generally required to transform into sustainable engineering guided by sustainability worldview and values. This section presents an overview of sustainable engineering and education. Sustainable engineering as an evolving and maturing engineering discipline is reviewed and some historical account of the discipline addressing origins and ambitions is provided. Thereafter, the definition and rationale of sustainable engineering as well as the philosophical underpinnings, frameworks, principles and tools of the discipline are discussed. Sustainable engineering education covering issues of pedagogy, curriculum, learning outcomes, learning and teaching techniques and sustainability research are addressed.

Overview of Sustainable Engineering

Originally joining the debate as 'engineering for sustainable development', the engineering discipline aimed to internalise the precepts of sustainable development in the conduct of engineering activities (Allen and Shonnard, 2012). This venture gave rise to industrial ecology, green engineering, earth systems engineering, and engineering tools such as life cycle assessment (LCA) and design for X (DfX) amongst several others. Although it is difficult to state precisely when and who coined the term 'sustainable engineering', the phrase is clearly useful for members of the engineering community convinced by the criticality of engineers in designing and engineering a sustainable future.

Defining Sustainable Engineering

The definition of sustainable engineering is currently unsettled given the contested nature of sustainability. However, it is worthwhile to attempt a definition of sustainable engineering with recourse to sustainable development. The most prominent definition of sustainable development remains the Brundtland Commission's "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987). The UNESCO Engineering Initiative (UEI) defines sustainable engineering as "*the process of using resources in a way that does not compromise the environment or deplete the materials for future generations*"

(UEI, 2017). Two other definitions of sustainable engineering worthy of note are given by Short (2008) and Gagnon *et al* (2012).

Whilst Short defines sustainable engineering "*as engineering that targets sustainable development*" (Short, 2008, p.24). Gagnon *et al* delineate it "*as the integration of sustainability issues in the various activities associated with engineering practice*" (Gagnon *et al*., 2012, p.50). It is simply stating the obvious that sustainable development is the raison d'etre of sustainable engineering. Thus, sustainable engineering inevitably inherited the imprecision and complexity of sustainability definition. Nonetheless, it is well-recognised that sustainability is not attainable from the current conventional engineering methods but from initiatives founded on the social, economic and environmental bases (Allenby *et al*., 2007). Table 2.2 presents some differences between conventional engineering and sustainable engineering.

Table 2.2. Conventional engineering vs. sustainable engineering approaches

Conventional Engineering	**Sustainable Engineering**
Considers the object or process	Considers the whole system in which the object or process will be used
Focuses on technical issues	Considers both technical and non-technical issues synergistically
Solves the immediate problem	Strives to solve the problem for infinite future
Considers the local context	Considers the global context
Assumes others will deal with political, ethical and societal issues	Acknowledges the need to interact with experts in other disciplines related to the problem

Source: Penn State *EME 807- Technologies for Sustainability Systems* lecture notes retrieved from: https://www.e-education.psu.edu/eme807/node/688 [Accessed 15 April 2017]

Sustainable engineering generally proposes a conceptual departure from conventional engineering and seeks to broaden the problem and solution domains of engineering across the three areas of economy, society and environment. Therefore, the discipline alternates among transdisciplinary, multidisciplinary and meta-disciplinary features as it struggles to not only establish itself but achieve the highly prized goal of engineering sustainability.

Rationale for Sustainable Engineering

Sustainable development, as discussed earlier, became necessary following the pressing "need to live within constraints and to ensure more fairness in access to limited resources" both intra- and inter-generationally. Contrastingly, sustainable engineering arose in recognition of the need for engineering activities such as the use of material, water resources and energy as well as infrastructure and product development to proceed sustainably. Thus, whilst the former in addition to being vital for policy, planning and decision-making emphasises change in lifestyle, the latter concentrates on engineering activities. Hence, sustainable engineering is a subset of sustainable development. The need for sustainable engineering can be discussed under various headings. However, for brevity, two factors shall be considered. These are the inextricable link between economic development and engineering, and the instrumental value of engineering in addressing sustainability challenges.

Economic Development and Engineering

Reference has already been made to the central role of engineering and technology in characterising economic activities in various geological periods. Indeed, as aptly expressed by Cropley in 2015, engineering and technology represent "the economic lifeblood of societies" (Cropley, 2015, p.13). Societies that were privileged with engineering and technological capabilities prospered as the recent history of world economies has shown. The link between economic progress and engineering has been widely acknowledged in literature and public discourse. In an address to members of the American Association for the Advancement of Science in 1895, William Kent illustrated the causal relationship between engineering and economic growth (Kent, 1895). Kent explained how engineering the Erie Canal brought prosperity to New York City. This canal-prosperity story has been replicated in the Suez Canal, Grand Canal and Panama Canal in Egypt, Venice and Panama respectively. The industrial development and maturing of the engineering profession in England in the 17-1800s is also a relevant example (Christopher, 2007). The same success story is related about railways, roads, air transport, internet, and about so many other engineering and technological products and services. Consequently, economic growth is evidently driven and enhanced by engineering and technology. Economic development, however, represents a cardinal requirement of sustainable development, and therefore expertise in the form of sustainable engineering is needed to deliver this goal.

Instrumental Value of Engineering and Technology

Another reason for sustainable engineering is the instrumental value of engineering in addressing real-world problems. Over the centuries, engineering and technological creativity has intervened to resolve societal issues and challenges including military constraints. In fact, the latter was so associated with engineering that when non-military problems were increasingly requiring intervention the field of civil engineering emerged to differentiate such interventions from military engineering activities. Staying with military challenges, in the 1860s in Paris there arose a need to rapidly deploy troops throughout the city in the event of any revolutionary uprising. This was sequel to events of 1848 in which Parisian revolutionaries, having gained the tactical advantage of cramped neighbourhood streets, effortlessly blockaded the passages and unleashed mayhem on hapless residents and government officials. The engineering solutions devised by Baron Haussmann are the novel, spacious boulevards for which the city of Paris is celebrated (Allenby, 2012). Examples of similar engineering interventions are so numerous that they may require a lengthy discussion. Nonetheless, in the modern era, which, as mentioned earlier, has been called the Anthropocene, the main challenge is delivering sustainable development. Engineering is again expected to address this problem, which is exclusively distinctive of the Age of the Human. However, this time it would be engineering reconceptualised as sustainable engineering and equipped with myriad tools to cater for environmental, economic and social needs.

Sustainable Engineering Frameworks

Sustainable engineering frameworks have been copiously proposed in the literature. Most of the frameworks are expectedly predicated on the concept of sustainable development. Furthermore, the frameworks are generally embodied by principles and tools related to several disciplines in both the social sciences and engineering. The integration of these components is usually presented as a sustainable engineering framework.

Sustainable Engineering Principles

Whilst developing a taxonomy of sustainable engineering principles under the various categories of ‘international’, ‘national’, and ‘researchers’, Gagnon *et al* enumerated 12 examples of sustainable engineering frameworks (Gagnon *et al*., 2009) These proposals are a list of guidelines featuring averagely between 5 – 17 principles aimed at providing guidance for sustainable engineering practice. The Institution of Professional Engineers of New Zealand details 17 guidelines while the Royal Academy of Engineering UK maintains a list of 12 guidelines. Other proposals of sustainable engineering principles include the Sandestin Green Engineering Principles, the Hannover Principles, and Coalition for Environmentally Responsible Economies (CERES) Principles. The Twelve Principles of Green Chemistry, the Augsburg Materials Declaration, Ahwanhee Principles, and Earth Charter Principles are also variously suggested as useful principles for sustainable engineering (Allen and Shonnard, 2012)

Engineering professional associations have equally included sustainability in codes of ethics which serve as guiding principles for the conduct of engineering activities. Indeed, sustainability is a requirement under the code of conduct of the Institution of Civil Engineers. The Engineering Council in the UK lists six principles of sustainable engineering including the need to “contribute to building a sustainable society, present and future”, “apply professional and responsible judgement” as well as “do more than just comply with legislation and codes”(Engineering Council, 2013). The remaining principles guide engineers to “use resources efficiently and effectively”, “seek multiple views to solve sustainability challenges”, and “manage risk to minimise adverse impact to people or the environment”. It is instructive that sustainable engineering principles were developed eclectically from environmental sciences, green chemistry, industrial ecology, and systems engineering among other disciplines. The fact that sustainable engineering harnesses these ideas in pursuit of engineering sustainability indicates its multidisciplinary posture.

Sustainable Engineering Tools

Similar to the extant principles which sustainable engineering is gradually adopting, a number of tools useful to the discipline subsist. Some of these mechanisms, which have already appeared in sustainable engineering literature, are Eco-Industrial Parks (EIPs), Pollution Prevention (P2), Life-Cycle Assessment (LCA), Design for X (DfX), and Leadership in Energy and Environment Design (LEED) (Cushman-Roisin, 2006). EIPs replicate or mimic the ecosystem by converging all industrial activities and associated enterprise in the same location. The idea is to promote interaction, synergy as well as close-loop practices especially amongst closely-related industries. P2 is an environmental science tool based on the fairly sensible notion of ‘prevention is better than cure’. The focus of P2 is to avoid pollution ab-initio through various strategies ranging from waste elimination, reduction, recycling to waste impact minimisation. LCA is quite a popular tool that considers the entire lifespan of a product, project or system from conception to retirement or interment (or as it is said, from ‘cradle to grave’). The process involves a holistic assessment of a project’s potential impact at each developmental stage from procurement of raw materials to use/consumption and eventual disposal.

DfX is a very useful process of product design which considers various desirable attributes represented as X, where X can be ‘assembly’ giving rise to design for assembly (DFA) or ‘environment’ resulting in design for environment (DfE) and so on. LEED Green Building Rating System™ is a programme developed by the US-based Green Building Council (USGBC) to assist in the certification of a building’s sustainability status. The programme has received wide acceptance and is currently the standard benchmark for erecting sustainability-compliant buildings (USGBC, n.d.). Figure 2.2 is an example of sustainable engineering framework found in the literature.

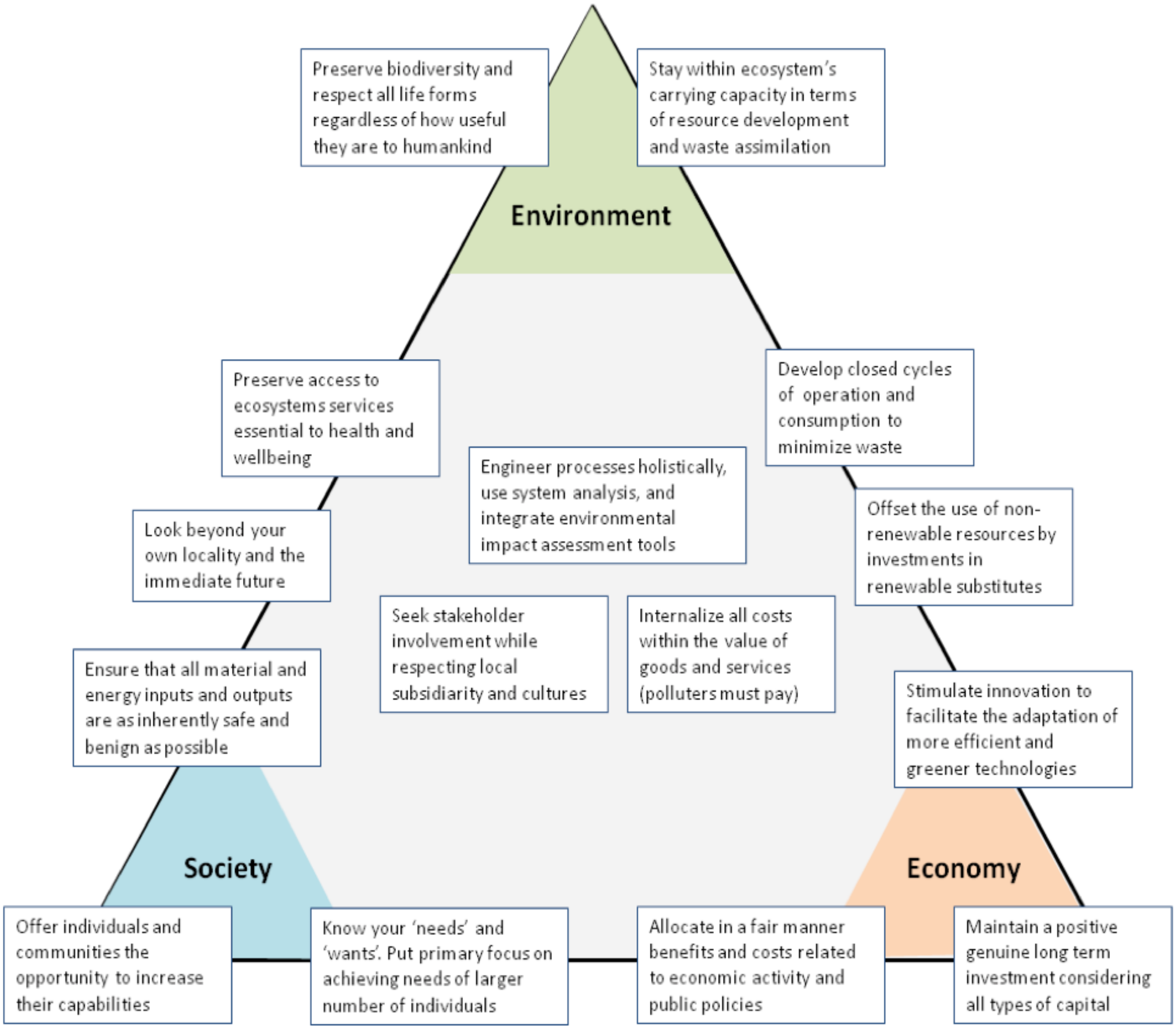


Figure 2.2. Proposed sustainable engineering framework
Source: Gagnon *et al*, 2009.

The above framework provides guidance on how to conceive and execute projects sustainably. Note that there are principles placed directly on each pillar of sustainability with some guidelines positioned between pillars. This is intended to guide engineering activities by ensuring that all possible issues and impacts, which may arise from any project, are duly considered. Hence, the framework severally features principles for the attainment of economic growth, societal progress and environmental protection, and also for the fulfilment of the nexus between society and environment, environment and economy, and economy and society.

Sustainable Engineering Education

Sustainable engineering education or simply engineering education for sustainable development (EESD) dawned as a corollary of ESD. The self-evident role of engineering in the existing crises of biodiversity loss, climate change, hyper-consumerism, and heightened water demand is linked to the rise of EESD. In response to these challenges, the engineering community devised EESD as an ethical and intellectual strategy. Since its rise, sustainable engineering education has stimulated an assortment of reactions. Advocates stress its potential to produce sustainability literate engineers, whilst critics emphasise the oxymoronic combination of the extant functionalist educational frameworks with sustainability engineering education. This difference of opinion has bolstered the sustainable engineering education discourse. An increased interest in teaching sustainable engineering has been reported in the literature (Sanjay, 2004; Fenner *et al.*, 2005; Kamp, 2006; Allenby, 2007; Huntzinger and Hutchins, 2007a; Byrne *et al.*, 2010a; von Blottnitz, Case and Fraser, 2015).

Temporally, the last two decades were critical to the rise of global sustainability concerns, which led to an unprecedented number of international declarations on sustainability education. Talloires Declaration in 1990 was the first global education declaration to bring into focus the responsibility of universities to produce sustainability literate citizens. University leaders from both developing and developed nations endorsed the Declaration laying the foundation for sustainability education imperative. The contagion of positives resulting from Talloires Declaration was so remarkable that by 2011 some 31 sustainability education declarations had been issued globally (Grinstead, 2011). The significance of these education declarations is the emergence of a sustainability education concept based on the recognition of education as an indispensable tool in addressing sustainability challenges.

The immediate popularity of the concept elicited interests from academic disciplines and professional associations seeking to implement sustainability education within their educational framework. Attempt by the engineering profession to take up ideas of sustainability education led to the creation of the World Engineering Partnership for Sustainable Development (WEPSD) in 1992 (Caroll, 1993). This partnership was formed by the World Federation of Engineering Organisations (WFEO), Union of International Technical Associations (UATI), International Federation of Independent Consulting Engineers (FIDIC) and the Consortium for International Earth Science

Information Networks (CIESIN). WESPD was partly motivated by the need to present a common engineering position at the United Nations Conference on Environment and Development (UNCED) which held at Rio de Janeiro in 1992. The participation of WESPD at the 1992 UNCED resulted in a unanimous call for international engineering organisations to act as the catalyst for the implementation of sustainability. The Partnership specifically stated that it would seek to 'redirect engineering ethics and education for sustainability' (Caroll, 1993).

In 2002, almost 10 years after WEPSD members attended UNCED 1992, the UN declared the period 2005 – 2014 as the Decade of Education for Sustainable Development (UNDESD). Following this declaration were several sustainability education efforts across the world. An exclusive declaration on engineering education for sustainable development was issued in 2004 in Barcelona. The Barcelona Declaration, as it came to be known, was prefaced by a sustainability narrative about increasing complexity and inadequacies of the extant socioeconomic development model. A new kind of engineer was recommended to possess a number of skills including an understanding of engineering's interface with society and environment. Application of systemic and holistic approach, ability to work in multidisciplinary teams and capacity to utilise professional knowledge according to deontological principles and universal ethics were equally recommended. Engineering education must, according to the Barcelona Declaration, be reoriented towards achieving these competences.

To consolidate on this success and monitor progress of the Barcelona Declaration, three European technological universities banded together to form the Engineering Education for Sustainable Development Observatory (EESD-Observatory). The Observatory was intended to check the progressive implementation of the Barcelona Declaration globally and present an episodic state-of-the-art review on international EESD strategies (EESD-Observatory, 2006). From 2002 onwards, EESD conferences as shown in Table 2.3 held around the world to assess and improve on sustainable engineering education efforts. Within this period, EESD made inroads into educational policies of numerous national governments as accreditation bodies, professional associations and university commissions introduced sustainability criterion as part of their certification requirements.

Table 2.3. Summary of EESD conferences

Serial	Year	Code	Theme	Venue	Remark
1.	2002	EESD02	Engineering Education for Sustainable Development	Delft, Netherlands	Maiden conference which clarified concepts and set the stage for successive meetings
2.	2004	EESD04	Engineering Education for Sustainable Development	Barcelona, Spain	Built on the preceding conference to review decisions and project into EESD trajectory
3.	2006	EESD06	Engineering Education in Sustainable Development	Lyon, France	Focused on progress made in EESD implementation which led to the ranking of universities
4.	2008	EESD08	Bridging the Gap	Graz, Austria	Deliberated on a range of EESD challenges and ways out
5.	2010	EESD10	Learning for Transformation	Gothenburg, Sweden	Focused on lessons learned from decades-long EESD efforts
6.	2013	EESD13	Rethinking the Engineer	Cambridge, UK	Stressed conceptual and philosophical approach to reshaping engineering activities
7.	2015	EESD15	Cultivating the T-shaped Engineer	Vancouver, Canada	Explored the challenge of cultivating T-shaped engineer through pedagogy and curricula reform
8.	2016	EESD16	Building a Circular Economy Together	Bruges, Belgium	The event considered how EESD implies the creation of a pollution-free economy

Sweden, for example, modified the Swedish Higher Education Act (1992:1434) in 2006 to mandate universities to "…promote sustainable development through their educational activities…"(Motrel *et al*., 2006) Similarly, the UK Standard for Professional Engineering Practice (UK-SPEC) detailing standards for Engineering Technician (EngTech), Incorporated Engineer (IEng) and Chartered Engineer (CEng) captured the issue of sustainability under its competence and commitment standards. Globally, such efforts have continued to be replicated with countries in Europe and North America in the vanguard. Sustainable engineering education initiatives in the developing world are progressing very slowly but the prospect of an acceleration is not farfetched. Already, African HEIs through the Association of African Universities (AAU) have acknowledged the indispensability of sustainability education in the 21st century. In 2009, the Abuja Declaration on ESD was issued in which African universities pledged to implement the Higher Education for Sustainable Development in Africa (HESDA) framework. The progress of African EESD, however, is not yet documented.

Sustainable Engineering Pedagogy

Interest in sustainable engineering naturally involves questions of pedagogy. How can sustainable engineering be taught and learned? What approach, strategy, or method is best suitable for integrating, incorporating or embedding sustainable engineering courses in engineering curricula? A number of pedagogical frameworks featuring novel ideas and strategies have been proposed. However, these proposals are as diverse and contested as are conceptions of pedagogy and curriculum. Clarification of these two important educational notions is hence germane.

Pedagogy and Curriculum

Pedagogy and curriculum have remained topics of impassioned discussion in the educational community. In the 19th century, Gabriel Compayre's (1843-1913) *The History of Pedagogy* published in 1889 furthered an ongoing debate by sketching the trajectory of pedagogy from classical antiquity. John Dewey (1859 -1952) followed with a series of unbridled critique on prevailing pedagogy in the American educational system. Another seminal contribution to the topic came from the Russian theoretician Lev Vygotsky (1896 -1934), who researched extensively into the psychology of education. Added to these intellectual endeavours in the 20th century was Paulo Freire's (1921-1997) *Pedagogy of the Oppressed*, which relaunched the pedagogical polemics. Currently, scholarly works on the subject of pedagogy and curriculum have continued to emerge (Kotecki 2002; Alexander 2004; Murphy 2008; Yeats 2013). The interest pedagogy has generated over the centuries is indicative of its centrality in educational discourse.

Pedagogy has been defined in the Cambridge Dictionary as the "study of the methods and activities of teaching". The Encyclopaedia Britannica describes pedagogy in terms of teaching methods, educational goals and ways to achieve these aims. Pedagogy is a word of Greek root derived from *paidagogos*, a compound of "*paidos*" (child) and "*agogos*" (leader) (NWE Contributors, 2015). This etymology leads to the delineation of pedagogy as simply the art and science of teaching children. Authors such as Knowles (1995) even argue for the exclusive use of pedagogy in reference to children’s education. Andragogy, coined by Alexander Kapp (1799-1869) from the Greek *andr* (man), is suggested for adult education. Initially gaining some currency, andragogy has now fallen into disuse. Pedagogy is presently the preferred term for the art and science of teaching generally. Trailing this definitional contention is the interesting question about the purview of pedagogy. The query of what constitutes pedagogy does not yield a harmonious response. Educational discourse in some quarters subordinates pedagogy to curriculum, while others express the opposing viewpoint that pedagogy involves teaching and learning with all the necessary concomitants including curriculum (Alexander, 2004).

Curriculum is of Latin provenance – *currere* meaning “to run the course”. There is an understanding of curriculum as the documentation of “why”, “what”, “when”, “where”, “how” and “with-whom-to-learn” of an educational programme (Kotecki, 2002). Conceived this way, curriculum is no more than a document containing information and guidelines. However, curriculum is also assumed to be a process involving the participation of various stakeholders. Two most common methods of curriculum development are “top-down” and “bottom-up” approaches. In the top-down approach, political and educational authorities initiate the process setting national parameters and standards for implementation by learning institutions. The “bottom-up” method describes a process that begins from the educational institutions with societal inputs and ends with an endorsement of a national government. A third approach termed “hybrid method” is emerging in which the “top-down” and “bottom-up” processes are combined for better results.

The sustainable engineering education community appreciates these complexities and upholds the generic and terminological conceptions of pedagogy. Furthermore, the notion of curriculum both as a document and a process is adopted. The third approach to curriculum development is also frequently suggested in sustainable engineering pedagogy. In addition to these conceptual underpinnings, sustainable engineering pedagogical frameworks are influenced by variously proposed learning outcomes. Using an assortment of didactic resources, suggestions concerning the end result of a sustainability education in engineering have been made. Therefore, the following sections shall discuss some of the learning outcomes of a sustainable engineering education.

Learning Outcomes for Sustainable Engineering

Learning outcomes are prominent features of modern educational systems. In the preamble of most academic subjects, courses, modules and programmes, a section on learning outcomes is typically inserted. These are usually statements of the expected end result of a learning activity or period. Several learning outcomes have been suggested for sustainable engineering education. Some of these propositions are contained in the Barcelona Declaration (EESD, 2004) and the publications of professional associations and accreditation bodies.

Barcelona Declaration

Barcelona Declaration is the outcome of the second EESD Conference in 2004 (see Table 3.2). It is arguably the first explicit and exclusive proclamation on sustainable engineering education. Premised on the indispensability of HEIs and the need for an engineering education response, the Declaration lists 7 proficiencies of a sustainable engineer. It states that engineers must be able to: (a) Understand how their work interacts with society and the environment, locally and globally, in order to identify potential challenges, risks, and impacts (b) Understand the contribution of their work in different cultural, social, and political contexts and take those differences into account (c) Work in multidisciplinary teams, in order to adapt current technology to the demands imposed by sustainable lifestyles, resource efficiency, pollution prevention and waste management (d) Apply a holistic and systemic approach to solving problems and the ability to move beyond the tradition of breaking reality down into disconnected parts (e) Participate actively in the discussion and definition of economic, social and technological policies to help redirect society towards more sustainable development (f) Apply professional knowledge according to deontological principles and universal values and ethics (g) Listen closely to the demands of citizens and other stakeholders and let them have a say in the development of new technologies and infrastructures.

In order to deliver these competences, sustainable engineering education must take on such qualities as integrated approach to knowledge, attitudes, skills and values in teaching. Also, the disciplines of social sciences and humanities must be incorporated in engineering education with the promotion of multidisciplinary teamwork. Other features required of a sustainable engineering education are critical thinking, creativity, ability to foster reflection and self-learning as well as systemic thinking. Finally, sustainable engineering education must be capable of raising awareness for the challenges posed by globalization. The Barcelona Declaration proclaimed that certain aspects of educational process should be reviewed including links between different levels of the educational systems. There are also issues of course content, teaching strategies, teaching and learning techniques, research methods, and staff training. Others are evaluation and assessment techniques, external participation in curriculum development and evaluation as well as quality control systems (EESD, 2004).

Professional Associations and Accreditation Bodies

As already noted, a number of professional associations and accreditation bodies developed principles and competences expected of 21st century engineers. The UK Engineering Council, for example, states in its third edition of the UK-SPEC that CEng should be able to develop solutions to engineering problems using new or existing technologies through innovation, creativity, and change. The document further requires CEng to demonstrate sustainability competences by being able to contribute to building a sustainable society, both present and future. Similarly, they should apply professional and responsible judgement and take a leadership role. UK-SPEC further requires CEng to do more than just comply with legislation and codes. It is also an expectation of CEng to seek multiple views to solve sustainability challenges, manage risk to minimise adverse impact to people or the environment, and use resources effectively and efficiently.

In the publication of New Zealand Institution of Professional Engineers, sustainability competences for engineers are detailed under the categories of maintaining the viability of the planet, providing for equity within and between generations, and solving problems holistically. The ideal of holistic problem-solving is expatiated by a couple of principles including the need for a systems-based approach, and subordination of technology to human needs and ecosystems viability. The American proposition for sustainability competency is contained in the criteria document of the Accreditation Board for Engineering and Technology (ABET, 2009). Engineering programmes are required to demonstrate that students attain an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, and ethical issues as well as health and safety, manufacturability, and sustainability. It is also required that students understand professional and ethical responsibility and possess the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and social context.

Similarly, ICE Task Group mentions such broad requirements as the ability to work with complex ill-defined problems, development of teamwork and communications skills, and ability to evaluate the merits and demerits of options (ThinkUp, 2011). Comparable offers are made by professional bodies in several other nations, such as Australia, the Netherlands, etc. (McCormick *et al.*, 2005; Glavič, 2006; Dabipi *et al.*, 2010; Phuong, 2013). Such involvement of accreditation and professional bodies in featuring sustainability competences as learning outcomes incentivises education institutions to develop appropriate pedagogies for sustainable engineering.

Pedagogical Framework for Sustainable Engineering

HEIs devised various strategies to imbue students with sustainability competences. Set to meet the numerous goals of a sustainability education, the strategies ranged from whole institutional intervention to curricular modification. The various sustainable engineering education initiatives can be generally described from three dimensions, namely model, approach and orientation as summarised in Table 2.4 (Arsat *et al.,* 2011).

Model

In the model dimension are the stand-alone model and the integrated model. Stand-alone model for an institutional-level change involves the creation of a sustainability centre or sustainability institute. Example of this model abounds in many universities such as the Centre for Sustainable Development at the University of Cambridge, Arizona State University's School of Sustainability and Centre for Sustainable Development at the University of Ibadan in Nigeria. These centres have been established for the purpose of research into sustainability issues. A stand-alone model with an objective of curricular modification may be in the form of sustainability module or course programme. The course or programme is typically intended to educate about sustainability without necessarily integrating into an existing programme. Examples of a stand-alone model are UCL's MSc Environment and Sustainable Development[15] domiciled at The Bartlett and MPhil in Engineering for Sustainable Development at University of Cambridge[16].

Table 2.4. Summary of dimensions characterising pedagogical strategies

Dimension	Component
Model	Stand-alone model
	Integrated model
Approach	Singular
	Dialectic
	Consensual
Orientation	Disciplinary
	Interdisciplinary
	Multidisciplinary

Source: Arsat *et al* (2011)

The integrated model seeks the embedding or incorporation of sustainability ideals into an institution, existing programme or module. Institutionally, a number of integrated initiatives subsist. These include amongst others the Integrated University Model (see Figure 2.3), Sustainability DNA Model and the Four C Model (see Figure 2.4) developed in the University of Plymouth, University of Gloucestershire, and Technical University of Catalonia (TUC) respectively. While the Four C Model seeks the unification of four salient components of a typical HEI in sustainability efforts including curriculum, campus, community and culture, the Sustainability DNA Model replicates DNA structure to pursue a holistic sustainability competence based on the interactions of six elements, namely operations, outreach, student, experience, teaching and learning, and research, management and support (Sivapalan, 2015). The Integrated University Model is based on a study conducted by some researchers in 2004 at TUC Barcelona, Spain (Ferrer-Balas *et al.*, 2004). Synergy was sought in the areas of research, education, university life, and communication to come up with an all-encompassing model.

[15] http://www.bartlett.ucl.ac.uk/dpu/programmes/postgraduate/msc-environment-sustainable-development
[16] http://www-esdmphil.eng.cam.ac.uk/

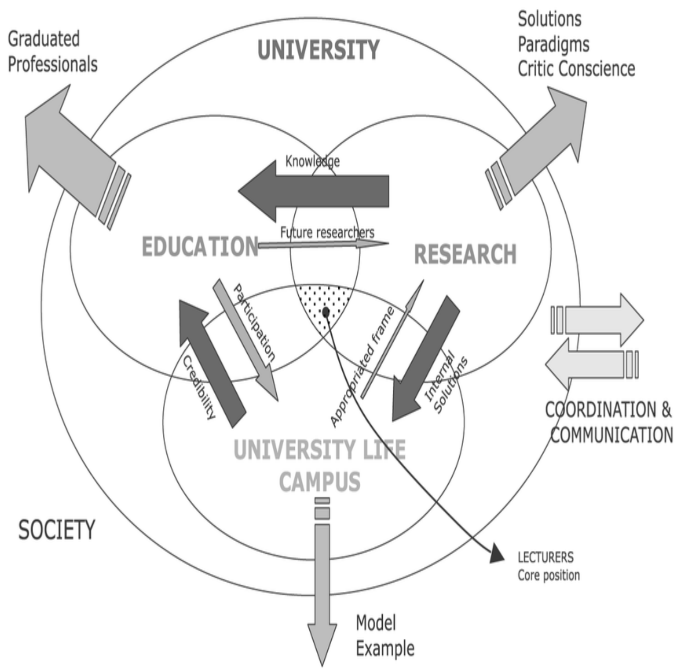


Figure 2.3. The Integrated University Model
(Ferrer-Balas *et al* 2004)

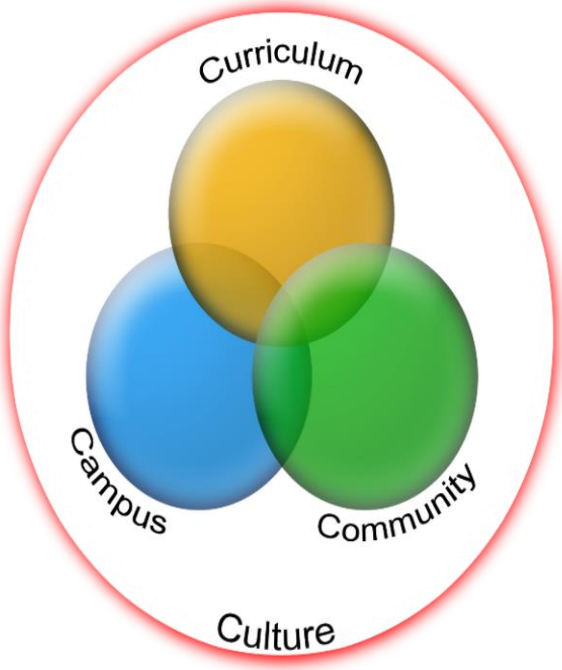


Figure 2.4. The Four C Model
(Sivapalan, 2015)

In the integrated model focusing on curricula, sustainability principles are purposefully synthesised in courses or programmes. The Applied Sustainability and Public Health in Civil Engineering offered at Queens University Canada is an example of such model (Arsat *et al.,* 2011).

Approach

The ways in which several HEIs have approached sustainability education initiatives can be delineated according to the three pillars of sustainability. As presented in Table 2.5, an approach can be singular, dialectic or consensual based on the dimension of sustainability emphasised. These distinctions, however, are most applicable at the level of curricular modification. The singular approach describes a situation in which one aspect of sustainability is introduced either as a stand-alone course or integrated module. An example of a singular approach is the *Environmental Systems*[17] module taught to students of UCL's MSc Environmental Systems Engineering. In this course, environmental sustainability is targeted. *Environmental Technology*[18] covered in the ABU's MSc Environmental Management is another example of the singular approach.

[17] https://sp.cege.ucl.ac.uk/study/Pages/Module-Guide.aspx?ModileCd=CEGEG016
[18] https://geography.abu.edu.ng/postgraduate_MSc/MSc.%20Environmental%20Management.html

Interestingly, economic and social dimensions of sustainability are not very popular courses in engineering education. Nonetheless, the UCL Institute for Environmental Design and Engineering runs a module entitled *The Social Dimensions of Sustainability*[19] in the context of environmental design and engineering.

The dialectic approach results in a programme or module that combines at least two sustainability pillars. Courses presented in this format tend to relate either social responsibility with economic factors or environmental issues with social impacts within an engineering context. This approach is exemplified by MIT's *Economics and Environmental Issues in Material Selection*[20] taught to undergraduate engineering students. Similarly, the module *Environmental and Resource Economics*[21] offered by MSc Environmental Management and Toxicology students of the Federal University of Agriculture in Nigeria exemplifies the dialectic approach. The consensual approach seeks development of a course or programme with a full sustainability content. This is perhaps the most desirable approach as illustrated by the MIT's *Design for Sustainability*[22]; a graduate level course. The course considers sustainability implications for engineering practice in relation to the built environment. In terms of the practicalities of an intervention approach, Allenby (2012) recommends the use of the non-engineering courses. The justification for this suggestion is the fact that a sustainable engineering course provides the context of modern engineering practice, whereas the traditional management courses are "of little relevance [and] quickly forgotten"(Allenby, 2012, p.401).

Table 2.5. Summary of the approach to ESD initiatives

Approach	Constituent
Singular	Environmental
	Social
	Economic
Dialectic	Environmental with social perspective
	Environmental with economic perspective
	Social with economic perspective
Consensual	SD consensual approach

[19] https://www.bartlett.ucl.ac.uk/iede/programmes/cpd-modules/modules/BENVGEE9
[20] http://ocw.mit.edu/courses/materials-science-and-engineering/3-080-economic-environmental-issues-in-materials-selection-fall-2005/
[21] http://pgschool.unaab.edu.ng/index.php/library-services/2014-10-30-11-03-21/department-of-environmental-management-and-toxicology
[22] http://ocw.mit.edu/courses/civil-and-environmental-engineering/1-964-design-for-sustainability-fall-2006/

Orientation

The orientation dimension characterises intervention based on disciplinary partnership with the possible outcomes of interdisciplinary, multidisciplinary, cross-disciplinary and transdisciplinary orientations. UCL's MSc Environmental Systems Engineering, which combines the disciplines of Environmental Engineering and Systems Engineering, is an example of interdisciplinary course. It is noteworthy that sustainable engineering inherently demands more than a monodisciplinary focus as already discussed. The pillars of sustainability are disciplines in their own right with a rich history of theoretical grounding and application. Hence, this orientation category may appear banal. However, the categorisation is not utterly misplaced as the tendency of engineering disciplines to approach sustainability with the typical silo-based perspective has been noticed. An example is given in Gardiner (2010) in which a sustainability module was taken by students of Industrial Engineering, and Information and Systems Engineering (Arsat *et al.,* 2011). The course proceeded in a monodisciplinary view that failed to make connection with wider sustainability concepts such as globalisation, etc. The outcome of this orientation was an inadequate sustainability knowledge.

General Sustainable Higher Education Matrix

A general matrix to integrate sustainability into HEIs was developed by Rusinko (2010) in a review of various options, some of which have already been discussed.

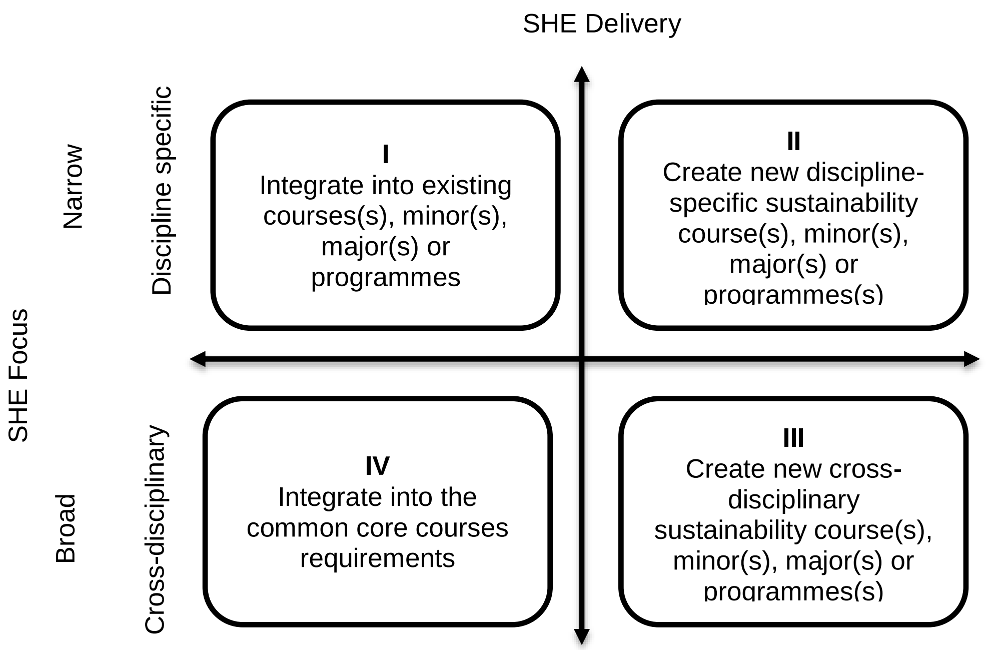


Figure 2.5. General Matrix to Integrate SHE (Rusinko, 2010)

Comprising four options as depicted in Figure 2.5, the matrix classifies the alternatives as either discipline-specific or cross-disciplinary. Quadrants I and II are discipline-specific and tend to have a narrow purview of sustainability principles. On the other hand, Quadrants III and IV are cross-disciplinary and cover broader issues. It is significant to note that the merit or demerit of options hinges on the extent to which the alternatives cover sustainability philosophies and also on their ease of implementation. Typically, the discipline-specific quadrants tend to be easily implementable but lack broad sustainability scope. In contrast, the cross-disciplinary alternatives exhibit robustness and consistency with sustainability ideals but face administrative hiccups.

Summary of Merits and Demerits of the Strategies

Table 2.6 summarises the merits and demerits of the strategies. Given that flexibility is recommended in implementing these strategies, the methods can be sequenced for more impactful outcomes.

Table 2.6. **Summary of merits and demerits of the strategies**

Serial	Dimension		Merit	Demerit
1	Model	Stand-alone	Easy to implement; Provides institutional sustainability identity	Insufficient coverage of sustainability
		Integrated	Best learning experience as it enables thorough sustainability thinking	Difficult to implement as it requires great resources
2	Approach	Singular	Easy to adopt	Fails to address at least two sustainability dimensions
		Dialectic	Less administrative hassle	Excludes at least one sustainability pillar
		Consensual	Consistent with sustainability ideals	Requires more resources
3	Orientation	Disciplinary	Easy to implement	Discordant with ultimate sustainability goals
		Interdisciplinary	Enriched focus	Requires more resources
		Multidisciplinary	Brings on multiple perspectives; Aligns with sustainability ideals	Administrative difficulties; Requires more resources
		Cross-disciplinary	Metadisciplinary benefits; Aligns with sustainability ideals	Administrative difficulties; Requires more resources

The Three-Tier Approach

The three-tier approach is a framework of sustainable engineering education designed by the University of Surrey (Azapagic *et al*., 2005). The approach comprises three elements as illustrated in Figure 2.6. The first step towards teaching sustainability to engineering students involves lectures and tutorials, which introduce students to the basics of sustainable development. Following the lectures are case studies intended to expose students to specific and practical sustainability-related issues to enable them appreciate engineering for sustainable development. In the third tier of the approach, integration of sustainability into the engineering curriculum is undertaken. This final tier also covers the overall aspects of engineering education, including fundamentals, quantitative methods, tools, and issues of clean technologies as well as engineering design. A strength of the three-tier framework is the gradual approach to integrating sustainability in the engineering curriculum. Such incremental process facilitates engagement with simple techniques before reaching the more complex ones.

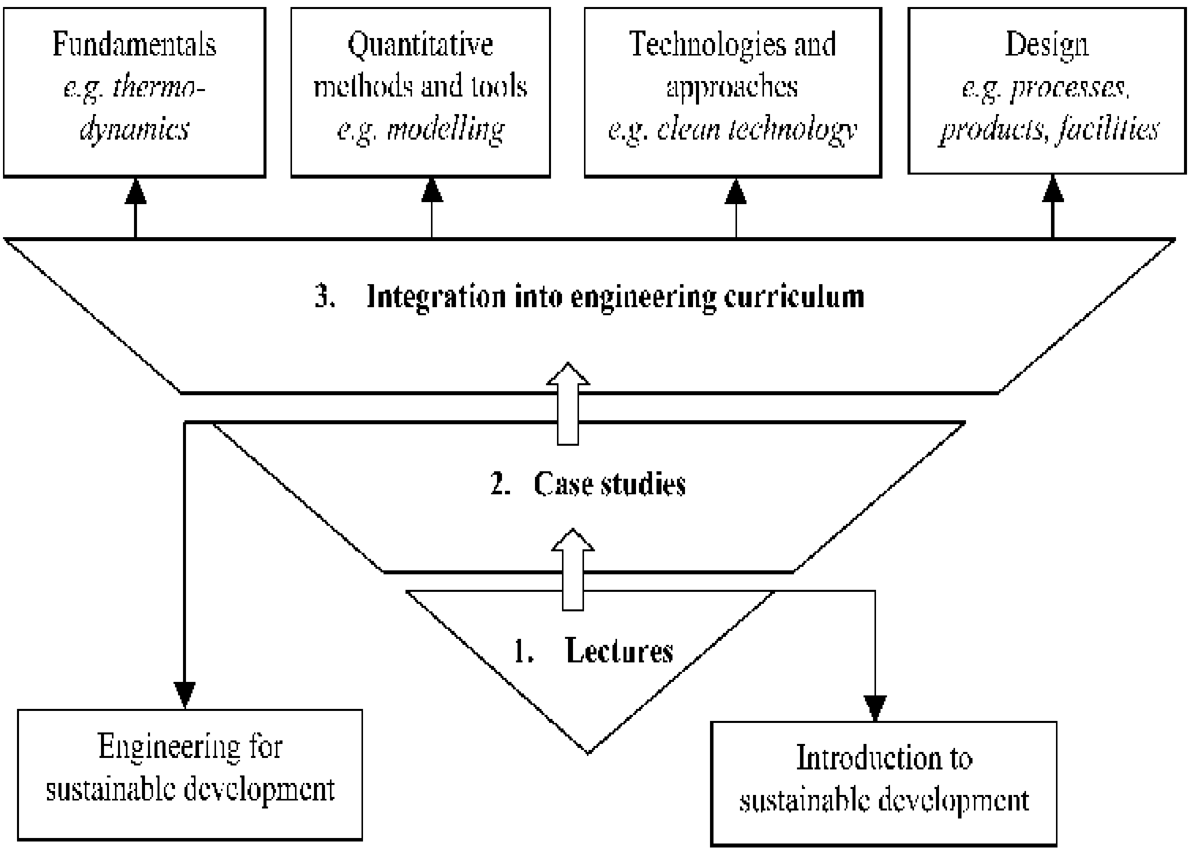


Figure 2.6. The three-tier approach of engineering sustainability education
Source: Azapagic *et al* (2005)

Sustainable Engineering Learning Process

Various learning and teaching techniques have been suggested for sustainability education. These techniques, which have been informed by the sustainability learning outcomes, feature both long-standing and novel methods.

Lecturing

Lecturing is a long-standing pedagogical technique that has been around since the emergence of universities. It is a mode of knowledge transfer that involves mainly two parties: lecturer and students. Lecturing has to do with the oral delivery or presentation of an educational material on a particular subject or topic. The definition of lecturing in various English dictionaries includes “exposition of a given subject before an audience”[23] and “a formal talk on a serious subject”[24]. Derived from the Latin *lectura*, which implies reading, lecturing has evolved to become the most conventional instructional method in HEIs. Unfortunately, lecturing technique is gradually losing traction as criticisms on the method continue to emerge in the literature (Heywood, 2005a; Shallcross and Robinson, 2007; Jones, Trier and Richards, 2008). Such criticisms usually stress how obsolete, undemocratic and ineffective lecturing has become. Additionally, the downsides of lecturing such as long preparatory hours, difficulty eliciting and sustaining students’ attention as well as requirements for visual and verbal supports are emphasised. Some remedial measures to address the deficiencies associated with lecturing have already been initiated. As an example, engineering lectures at UCL are interspersed with such activities as seminars, group discussions, etc. aimed at engaging students with a view to achieving active and student-centred learning. In the context of sustainable engineering education, lecturing technique is suitable for introductory sessions on the fundamentals and basics of sustainability. Hence, HEIs offering sustainability courses employ lecturing technique for such purposes.

CDIO Initiative

In October 2000 a worldwide effort dubbed *The CDIO Initiative*, which is an initialism for Conceive-Design-Implement-Operate, was launched. Initially conceived at MIT in

[23] http://www.thefreedictionary.com/lecturing
[24] http://dictionary.cambridge.org/dictionary/english/lecture

the 1990s to reform engineering education, the CDIO project intended to develop and codify abilities expected of contemporary engineers. With the aid of a stakeholder focus group comprising student, engineering faculty members, and industry representatives, the CDIO Syllabus was prepared. The entire CDIO Initiative is guided by the understanding that "every graduating engineer should be able to Conceive-Design-Implement-Operate complex value-added engineering products, processes, and systems in a modern, team-based environment" (Crawley *et al.*, 2014, p.12). The CDIO Syllabus is divided into four high-level expectations as illustrated in Figure 2.7.

4. CDIO (Conceive-Design-Implement-Operate		
1. Technical Knowledge and Reasoning	**2. Personal and Professional Skills**	**3. Interpersonal Skills**

Figure 2.7. Building blocks for CDIO (CDIO 2010)

The first level presents the *technical knowledge and reasoning* expected in modern engineering professions. The development of this engineering fundamental prepares students to imbibe skills necessary to begin a professional career. This expectation however varies widely from one engineering field to another. The next level suggests that a mature individual interested in technical endeavours possesses a set of *personal and professional skills* which are central to the practice. In order to work in a modern team-based environment, students must have developed the *interpersonal skills* of team work and communication corresponding to the third expectation level. Finally, in the fourth level of expectation, a student must understand something of conceiving, designing, implementing, and operating systems in the enterprise and societal context to be able to actually create products and systems (CDIO, 2010).

The CDIO approach to educating engineering students is important for sustainability education. Coral (2009) mapped sustainability programme outcomes against these four levels of CDIO Initiative and came up with a taxonomy of expectations. Featuring prominently in this classification are transdisciplinary approaches characterised as elements of systems thinking. The personal and professional skills component of the CDIO fits with sustainability competences of commitment and understanding of the potential impact of new scientific discoveries, and social impact of new technologies and innovations. The final level, which is the CDIO, corresponds to the need for aesthetics and human factors as well as environmental sustainability in designing. The "operate" subgroup features considerations for end of useful life, disposal options, and residual value at life-end. Consequently, employing CDIO technique in the teaching of sustainability to engineering students could be very useful.

Problem-Based Learning

Problem-based learning (PBL) is one of several pedagogical innovations that arose in the 1960s as part of student-centred learning initiatives (Alwi *et al.*, 2012). Educators at McMaster University in Canada followed by academics in Maastricht University in the Netherlands are credited with the introduction of PBL (Holgaard *et al.*, 2015). The approach places problem at the centre of students' learning and encourages them to seek solutions in a self-directed way. Usually working in small groups with teachers acting simply as facilitators, students attempt to proffer solutions to a deliberately ill-defined, ill-structured, and open problem. An essential idea in PBL is that a problem is not necessarily expected to be solved but to serve in initiating the learning process (Kolmos and De Graaff, 2014). PBL technique is based on the understanding that students are not only motivated but attain better comprehension by working on a problem that replicates real-life situations. Since its introduction, PBL has been implemented in several HEIs across the world. In UCL-run MSc Environmental Systems Engineering, PBL is applied in the delivery of modules such as *Systems Engineering Management*, in which students are exposed to problem-solving process.

PBL as originally conceived at McMaster and Maastricht Universities is guided by the following learning principles: (a) Problems form the focus and stimulus of learning (b) Problems are the vehicle for development of problem-solving skills (c) New information is acquired through self-directed learning (d) Student-centred (e) Small student groups (f) Teachers are facilitators/guides. Over the years, these learning principles have guided PBL implementations giving students opportunity to work out learning needs and to connect learning with the outside world. Increased students' motivation for learning, improved retention rate and higher grades have been reported as benefits of PBL technique, although heightened students' stress tend to occasionally occur (Huntzinger and Hutchins, 2007b).

Somewhat relatedly, Wilkerson and Gijselaers (1996) listed the following three basic learning theory principles stressing the constructivist nature of PBL. Firstly, learning is a constructive and not a receptive process. Secondly, metacognition affects learning, and finally, social and contextual factors influence learning. The implication of these principles is that cognitive learning alone is inadequate to the development of a PBL model. PBL is important in the engineering field as engineers engage in problem-solving. The interdisciplinary nature of problems means that engineering students should be encouraged to use knowledge from different fields for problem analysis and problem-solving. Sustainable engineering as already highlighted acknowledges the complexity of contemporary engineering challenges; hence, PBL is an invaluable technique in sustainable engineering education.

Project-Based Learning

Project-based learning (PjBL) is another departure from traditional teaching approach. Similar to PBL, PjBL is inspired by the need to engender active learning amongst students. Within PjBL framework, knowledge is sought through inquiry usually related to students' experiences of the outside world. Students are assigned projects, and mimicking a real work environment, they formulate questions, postulate hypothesis, review literature, discuss and critique ideas, and possibly make new discoveries. Teachers in the PjBL model usually serve as supervisors. The rationale for such approach is rooted in a key learning sciences idea which connects students' personal investment in learning with their engagement in meaningful tasks that replicate real-world situations (Bell, 2010). A distinction is made between learning that ensues from memorisation of discrete facts and the one resulting from meaningful participation in context-related tasks. The latter distinction is the hallmark of PjBL.

Project-based and problem-based learning methods are often conflated not only because they share a common "PBL" abbreviation, but also due to the shared feature of student-centred approach. The tendency to merge these approaches has led some authors to separately abbreviate problem-based learning and project-based learning as "pbl" and "PBL" respectively (Krajchick and Blumenfeld, 2006). However, PjBL could be adopted as a more convenient abbreviation of project-based learning. Notwithstanding the shared aspects between PjBL and PBL, certain dissimilarities exist. For instance, PjBL projects culminate in artefacts, realistic products or presentations, whilst PBL problems may only serve to initiate the learning process. Thomas (2000) lists five criteria for PjBL as follows: (a) Project-based learning projects are central, not peripheral to the curriculum (b) Project-based learning projects are focused on questions or problems that drive students to encounter the central concepts and principles of a discipline (c) Projects involve students in a constructive investigation (d) Projects are student-driven to some significant degree (e) Projects are realistic not school-like.

Positive feedback has been received from PjBL implementations in various HEIs (Gülbahar and Tinmaz, 2006). Students' communication skills, collaborative abilities, and critical as well as creative proficiencies have been observed to improve dramatically. Other benefits of the technique include development of positive attitude towards learning, problem-solving, confidence, and self-esteem which are essential for gaining deeper understanding. However, a drawback of PjBL is that it is a time-consuming process owing to a series of activities and sessions including selection of suitable topics, problem analysis by students, class administration, use of visual aids and other cognitive tools (Kolmos and De Graaff, 2014). In spite of these potent downsides, PjBL is a popular pedagogical technique as it facilitates the attainment of sustainability education learning outcomes and competences.

Case-Study Method

Case study is a learning tool employed in both teaching and research. The history of case study as a teaching technique extends back to 1870, when a law educator, Christopher Langdell, introduced the method at Harvard Law School (Davis and Yadav, 2014). Justifying the initiative on the need to prepare law students for real-world practice, Langdell replicated courtroom scenarios by exposing students to original court cases. Through classroom discussions and dialectics students drew their own conclusions. This was a complete departure from the hitherto Dwight Method, which stressed rote memorisation of legal heuristics, theories, and core principles (Breslin and Buchanan, 2008). Following Langdell's success in case-based teaching, Harvard Business School adopted the method in 1920. Over the years, case study as a teaching tool made inroads into other disciplines including engineering.

In engineering, a case is understood as "a written account of an engineering job as it was actually encountered"(Davis and Yadav, 2014, p.162). The emphasis of a case-based pedagogy in engineering is on the real-world context within which engineering activities happen. Attention is given to complex factors such as human interaction, subtlety of inanimate objects, time constraints and pressure of resources, which may not be adequately treated in a lecture-based instruction (Davis and Yadav, 2014). The objective of case study in engineering education is akin to that of other disciplines, which is to expose students to the complexities and ill-structured characteristics of the fields that subsist in the gap between theory and practice. The following elements are suggested by Merseth (1994) to generally characterise cases: (a) Cases are based on real-life events or realistic situations that allow students to experience problems they are not likely to encounter first-hand (b) Cases present both contextual and technical information that is based on careful research and study (c) Cases may present no clear-cut solutions to allow students to develop multiple perspectives.

In the light of this characterisation, four case study-based teaching approaches have been delineated including critical instance case, case problem, state-of-the-art case, and case history (Davis and Yadav, 2014). Whilst critical instance case proceeds with the provision of background information requiring students to come up with a suitable line of action, the case problem presents a problem with a mix of relevant and irrelevant data to allow students to practice critical and analytical skills to arrive at a justifiable decision. The state-of-the-art case proceeds by acquainting students with insights into the edges or frontiers of knowledge or discovery in a field seeking for suggestions on advancement. In the case history approach, learners are presented with real engineering works detailing project phases, procedures, achievements, challenges and mitigating measures (Heywood, 2005b) . Hence, case study is a versatile tool suited for a variety of pedagogical purposes. There is already a widespread use of this didactic method in sustainable engineering education across many HEIs (Dodds and Venables, 2005; Wei *et al*., 2014).

UCL Engineering Curriculum

Engineering has been taught at UCL for almost two centuries. Since UCL founded the world's first laboratory devoted to engineering education in 1827, students have been trained in various engineering disciplines (UCL Engineering, no date). Presently, the UCL Faculty of Engineering Sciences offers such core engineering programmes as biochemical, biomedical, chemical, computer, civil, electronic and electrical, and mechanical engineering. Engineering programmes at UCL run for three years, culminating in a bachelor's degree in engineering (BEng). A fourth year is required for the award of a master's degree (MEng). During the three-year period of the BEng programmes, students undertake engineering courses and training that begin with a lesson on the theoretical basis of their chosen disciplines. Also taught in the first year are lessons in mathematics and professional skills, which are delivered in shared classes with other engineering students as part of the Integrated Engineering Programme (IEP).

The IEP is an innovative integrated pedagogical framework that facilitates the delivery of specialist and interdisciplinary engineering education (see Figure 2.8). Within the interdisciplinary pedagogy, core engineering disciplines are taught in combination with crosscutting subjects, such as design and professional skills, connected systems, environmental engineering, and finance and accounting amongst others. An objective of the IEP is to produce engineering graduates with a grounding in the fundamentals of their chosen disciplines, but also adept at leadership, teamwork, and communication skills. As an industry-oriented curriculum, the IEP framework provides engineering students with the opportunity to partake in activities that replicate real-world engineering projects. The IEP is designed such that students register for a core discipline, but engage in interdisciplinary exercises alongside the core subjects. Students select a set of three IEP minors in the first year that will be taught across the second and third years. There are currently 18 IEP minors available to students (see Table 2.7). The UCL IEP could be a useful way of delivering sustainability education.

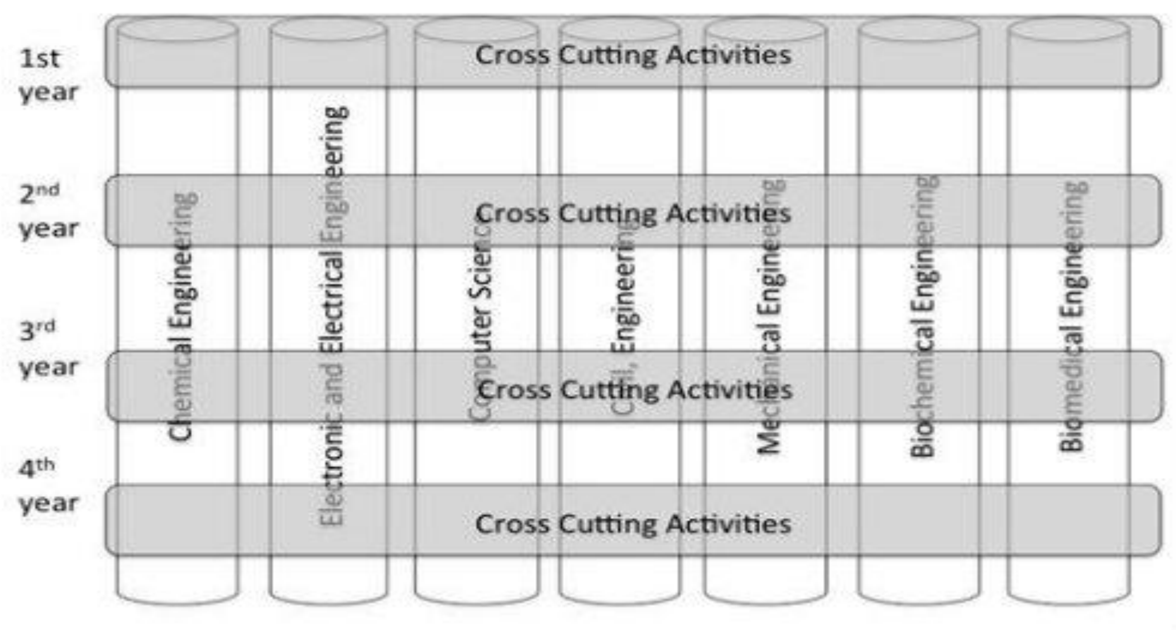


Figure 2.8. UCL IEP Framework
Source: http://www.engineering.ucl.ac.uk/integrated-engineering/programme-structure/

Table 2.7. List of UCL IEP Minors

UCL IEP Minors		
Strategic thinking in engineering and technology Connected systems Environmental engineering Finance and accounting Engineering and public policy Management	Manufacturing the future: regenerative medicines Modern applications of engineering mathematics Modern foreign languages Nanotechnology Entrepreneurship Crime and security engineering	Ocean engineering Intelligent systems Applied chemistry and molecular engineering Biomechanics Biomedical engineering Programming

Source: http://www.engineering.ucl.ac.uk/integrated-engineering/programme-structure/

Research in Sustainable Engineering Education

Research into sustainable engineering education continues to be undertaken within diverse contexts and focus. However, the dominant context of such studies has been the developed world. There is comparably little research into ESD/EESD in the context of a developing world as the reviewed literature shows. Developed countries whose sustainability education efforts have been studied include US, UK, Australia, Germany and several western European nations. Few studies attempted to bridge this gap by focusing on such developing countries as Vietnam and Malaysia. A brief overview of these studies is therefore considered.

Seeking answers to questions about competences, pedagogy and curriculum in relation to sustainability education in engineering, Segalas (2009) conducted a research involving five European technological universities. The work was a Eurocentric effort guided by the provisions of European Higher Education Area (EHEA) framework. The European nations covered in the research were Spain, Sweden, The Netherlands, Ukraine, Belgium, Scotland and England. Sustainability competences formulated as a tripartite of knowledge/understanding, skills/abilities, and attributes were addressed ab initio as requirements of 21st century engineers. Establishing these competences, the research proceeded to analyse how educational processes can provide suitable pedagogies to achieve sustainable development learning objectives amongst engineering graduates (Coral, 2009).

The study found that a succinct and unambiguous statement of sustainability competences was crucial to sustainable engineering education design. Another vital finding of the research was that sustainable engineering education needed a multi-pedagogical active methodology. In this regard, Enquiry Based Learning (EBL) strategies such as PjBL, case studies, role play and back-casting were essential. The question of curriculum revealed dissonance with the ideal situation in which sustainable development is embedded piecemeal and course wise. Lack of sustainability comprehension and dearth of top-down and bottom-up collaboration contributed to this impasse. The study concluded that this trend must be reversed as sustainability education processes are facilitated by an integrated approach involving all HEI constituents. Notwithstanding its immense contribution to sustainable engineering education and the sustainability education community, Segalas' research is limited by a Eurocentric focus. Consequently, the findings of the investigation may not be wholly applicable in a non-Western context.

In 2013, motivated by the desire to contribute to sustainability education in Vietnamese engineering HEIs, AI Phuong (2013) undertook an empirical study with a view to achieving this goal. The study intended to build culturally appropriate strategies for transforming engineering curriculum in Vietnamese HEIs into a sustainability-focused model. Questions formulated by the research focused on Vietnamese response to the challenges of sustainable development and the implications for Vietnamese engineers as well as the underlying issues of sustainable engineering education transformation and development of culturally fitting strategies. The research successfully mapped extant sustainability education efforts in Vietnam revealing commendable progress manifest in governmental commitment to the erstwhile UNDESD and in a series of seminars, conferences and educational policies on sustainability education. An important outcome of the research was a framework made up of six components including resources, vision, communication, professional support, motivation and cooperation (Phuong, 2013).

Informed by the evidenced-based understanding that "societal cultures, along with local economic, political and religious conditions act as mediators and filters to policies and practices imported from overseas" (Dimmock and Walker, 2000, p.307), the research aligned the framework components with Vietnamese culture. The study also found that issues hindering current sustainable engineering education efforts in Vietnam were somewhat intertwined with enduring Vietnamese values, attitudes, experiences and behavioural preferences. Stakeholders involved in educational processes including governmental authorities, NGOs, engineering businesses and universities variedly contributed to the Vietnamese response and would remain invaluable for future progress. The attempt of the research to consider sustainability education in a developing world context is quite commendable. However, any effort to universalise the findings across all developing nations could be challenged on the same grounds of socio-cultural differences. Hence, the research serves as a confirmation of the practically consensual position that sustainability education intervention is necessarily context-dependent.

Akin to Al Phuong (2013), Sivapalan's (2015) research was undertaken within a developing world context. The research proceeded by developing thirty sustainable development competences from a number sources including publications of Malaysian Engineering Accreditation Council and ESD literature. The research employed a case study method to explore the views of stakeholders working in a private HEI in Malaysia. Areas of specific interest in the research included the extent to which the HEI incorporated ESD in its engineering curriculum. Also queried was how to include sustainable development programmes and module learning outcomes within the undergraduate engineering programmes. The study equally sought to establish the need for additional components in a sustainable engineering education framework for the undergraduate programmes in the Malaysian HEI (Sivapalan, 2015).

The findings of the research resulted in the formulation of guidelines for a holistic incorporation of sustainable development competences and also in the design of whole institution EESD framework. Although the implications of the study's outcome are significant, especially to the Malaysian HEIs, the research's focus on a single university represents an important limitation. It would be difficult to generalise the findings of the research without some effort at circumspection. Also, the proposed guidelines for the incorporation of sustainable development competences in the undergraduate engineering programmes may not be wholly applicable to other Malaysian HEIs owing to administrative and other nuances.

Beringer *et al* (2008) assessed the status of sustainability efforts in HEIs across Atlantic Canada. Their research examined the level of sustainability integration in the Canadian HEIs covering curriculum amongst other areas. The assessment used a questionnaire to obtain data, which were triangulated with a content analysis. The researchers found that the majority of the HEIs had responded positively to sustainability, with some deficiencies in the aspects of physical operations, staff development and student opportunities. The curricular sustainability content ranged from minimal to substantial, with three-quarter of the HEIs embedding sustainability into traditional disciplines. In a related work, Watson (2013) undertook a content analysis of the civil engineering curriculum at Georgia Institute of Technology and discovered that the integration of sustainability was biased towards the environmental dimension. The findings substantiate the existence of a disproportionate spread of sustainability in the curriculum (Byrne *et al.*, 2010; Sinnott and Thomas, 2012; Shields *et al.,* 2014). Overall, Watson found a strong evidence of sustainability in the civil engineering curriculum.

In the African context, research into the sustainability content of engineering curriculum is scarce (Manteaw, 2012; Akeel *et al.*, 2017). This is not unexpected of a region whose HEIs teach sustainability mainly "as a fringe aspect of a limited number of disciplines" (UNEP-MESA, 2009, p.20). Manteaw argues that besides the UN-backed Mainstreaming Environmental Sustainability in African Universities (MESA), there is no visible sustainability education programme in West Africa. The studies that have considered sustainability learning on the continent have generally reported a low sustainability presence in the curriculum (UNEP-MESA, 2009; GUNi *et al*., 2011; UNESCO, 2014; Etse and Ingley, 2016). In Ghana, Etse and Ingley studied a polytechnic programme and discovered that sustainability courses were largely absent from the curriculum. Social sustainability appeared more than the environmental and economic themes. Contrastingly, in a case study of Rhodes University in South Africa, Togo (2009) discovered that sustainability had permeated teaching, research, and operations of the university. Although it did not feature engineering courses, the study found the sustainability content of the programmes to range from nil (accounting) to high (environmental sciences).

A research which sought to answer the question of how much engineering students know about sustainable development was undertaken in 2005 by Azapagic *et al* (2005). The study proceeded as a world-wide survey of engineering students inquiring about their level of knowledge and understanding of environmental and sustainable development issues. Justifying the study on the need to facilitate the integration of sustainable development in the engineering curriculum, the authors designed a web-based, self-completion questionnaire. The appraisal was prefaced and contextualised as an environmental and sustainable development study. Using a four-point Likert scale (*not heard of, heard of but could not explain, have some knowledge, know a lot*), the engineering students were asked to rate their knowledge of a range of topics including environmental legislation, standards, policy, technology, tools, approaches and sustainable development. The link to the survey was sent out to several universities around the world.

The outcome of the study was that engineering students largely exhibited a low level of sustainability knowledge. The research also suggested that much more effort was needed to educate engineering students on sustainable development. An interesting insight from the study was that, on average, the students were comparatively more aware of environmental issues than they were of social and economic sustainability. Interestingly, the students indicated strong personal relevance and professional importance of sustainability issues. However, the study had some limitations. Although it had ambitiously sought the participation of several engineering students across the world, the survey was responded to by students mainly from universities in Europe and America. Not a single African university was involved in the study as surveys sent to HEIs in that region were not returned. Moreover, there was an overrepresentation of chemical engineering students, who constituted 75% of the respondents. Thus, conclusions from the study, even though invaluable, must be done cautiously.

In 2014, Zwickle *et al* (2014) assessed the sustainability literacy of the undergraduate students at The Ohio State University. Over 1,000 students participated in the web-based and campus-wide survey, which featured 16 multiple-choice questions covering the three sustainability domains – economy, environment, and society. Being campus-wide, the test involved students from several academic disciplines including the engineering sciences, although this was not explicitly categorised. One of the objectives of the test, according to the researchers, was to quantify the students' knowledge of sustainability, both as a broad and an abstract concept. The featured questions encompassed the fundamental ideas of sustainability as represented in each of the three sustainability pillars. Since the test was administered in the US, some of the questions were necessarily US-specific. The test results were reported as mean percentages of student responses to the multiple-choice questions.

The study discovered that an average of 69% of the students answered the questions correctly. Across the three sustainability domains, a significant majority (>70%) of the students answered the environmental and economic questions correctly. Only about three-fifths of the students responded correctly to the social questions. An interesting question that enquired about the function of the ozone layer returned over 90% correct responses. Contrastingly, a question that sought the most commonly used definition of economic sustainability was answered correctly by just 46% of the students. Across class rank, the results showed that the performance of freshmen on the test was lower than that of the sophomores and juniors. A surprising finding reported by Zwickle *et al* was that aeronautical engineering students perfomed better than the rest of the students. Although the study represents an important contribution to sustainability education, it could have extended the literacy test to the educators. This would have provided an insight into how the educators compared with the students.

Summary

Sustainability is conceived as a state of affairs in which the needs of the present generation are met without undermining the potential of future generations to meet their needs. To educate a society for sustainability, the aims for which education has been sought are illuminating. Three educational aims in society have been *for salvation, for the state,* and *for progress.* Whilst education for salvation considers the acquisition of knowledge as a preparation for an afterlife, education for the state is basically intended for values such as social cohesion, patriotism, nationalism, and even, imperialism. Education for progress focuses on materialistic advancement with emphasis on personal fulfilment and economic satisfaction. Sustainability education evolved through a series of declarations and conventions within a milieu constituted by the educational aims. This chapter provided a brief historical account of the concept of sustainability. Based on insights from the three educational aims, the chapter highlighted the purposes for which sustainability education evolved. Some fifteen sustainability education declarations were reviewed and the resultant sustainability education construct was critiqued.

Sustainable engineering education is a moral and intellectual strategy devised by the engineering education community to address sustainability. The rise of sustainable engineering education was accelerated through various declarations and conferences especially UNDESD and Barcelona Declaration. EESD-Observatory was formed to relentlessly pursue and monitor implementation of sustainable engineering education globally. This chapter detailed the various pedagogical frameworks employed in teaching and learning about sustainable engineering clarifying the conceptions of pedagogy and curriculum. Learning outcomes of sustainable engineering education recommended in the Barcelona Declaration and publications of some professional associations and bodies were discussed.

The chapter further highlighted the ways sustainable engineering has been introduced in HEIs around the world. In addition, some learning and teaching techniques such as lecturing, CDIO initiative, PBL, PjBL, and case-study methods were explained as vital constituents of a sustainable engineering pedagogy. The chapter equally reviewed some research works in sustainable engineering education and noted how sustainability studies have been skewed towards the developed world. Sustainability research in the context of the developing world is gradually increasing but universalising the research findings across the developing nations is a formidable challenge. The next chapter explores the prospect of sustainable engineering education research in Nigeria.

Chapter Three

3 Research Context: Nigeria

Introduction

The purpose of this chapter is to review sustainability initiatives in Nigeria in relation to engineering education in the country. It seeks to establish from the literature the status of Nigerian sustainable engineering education. An important guide of the review is what Nigeria has accomplished so far in the implementation of sustainability education. The chapter highlights engineering practice in Nigeria before outlining the Nigerian educational system. Thereafter, sustainable development efforts in Nigeria including sustainability education initiatives are considered.

Country Overview

Nigeria (Figure 3.1) is an important African country with a population of over 180 million people and a landmass in excess of 900,000 square kilometre (UNdata, 2016). The country is ranked 152 out of 188 countries in terms of human development. With a HDI value of 0.527, Nigeria is considered a low human development country (UNDP, 2016b). Table 3.1 presents Nigeria's HDI trends from 2005 to 2010, showing a 13% increase in the HDI value. Furthermore, Nigeria's life expectancy at birth rose by 4.4 years, whilst mean years of schooling and expected years of schooling increased by 0.8 and 1 year respectively. Based on the most recent data (UNDP, 2016a), the multidimensional poverty index for Nigeria is 0.279, with more than half (51%) of the population being multidimensionally poor. An additional 18.4% are estimated to live near multidimensional poverty (NBS, 2010). However, Nigeria has increasingly shown commitment to improving its national circumstances.

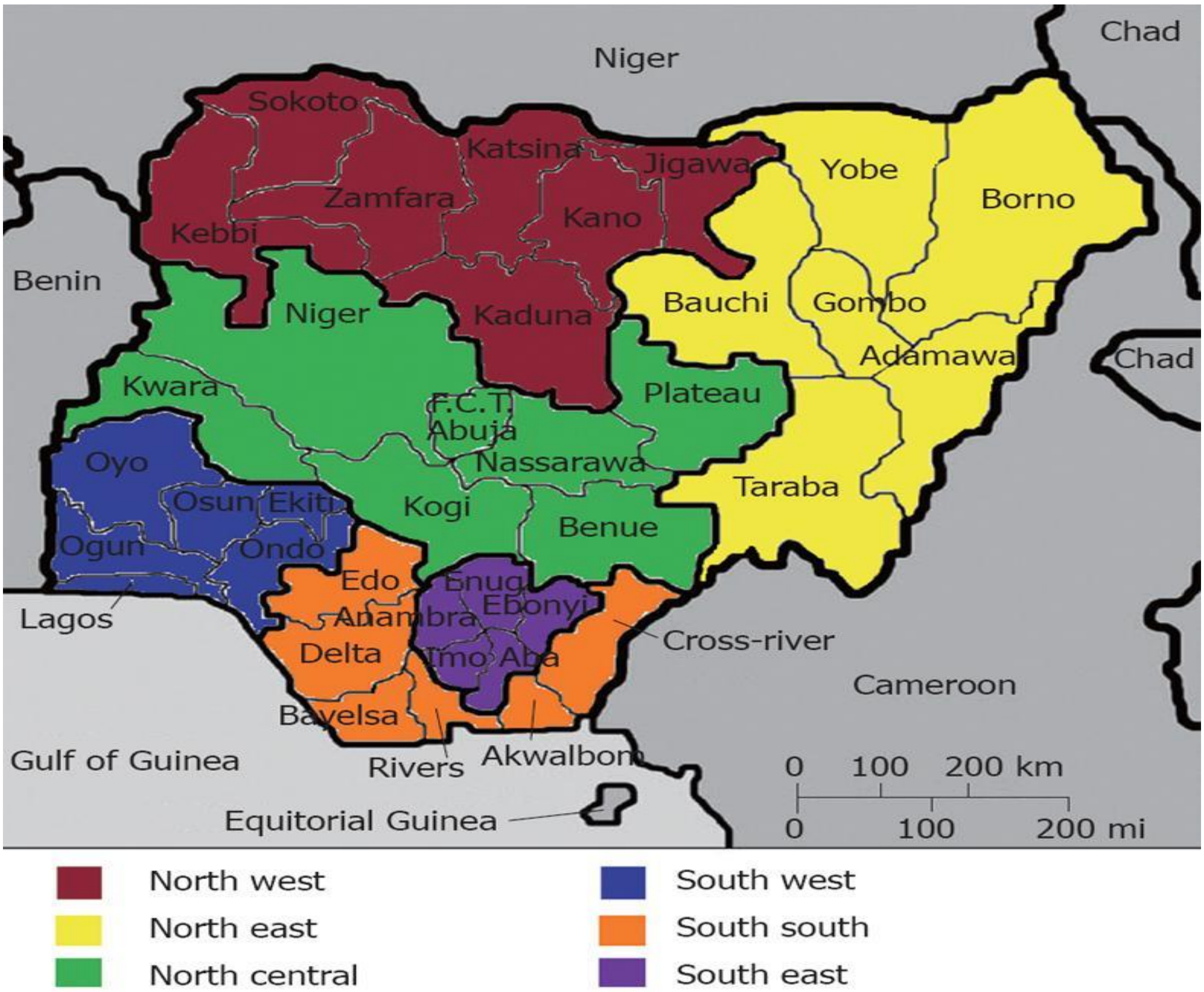


Figure 3.1. Nigeria's six geopolitical zones

Table 3.1. Nigeria's HDI trends since 2005

Year	Life expectancy at birth	Expected years of schooling	Mean years of schooling	GNI per capita (2005 PPP$)	HDI value
2005	48.7	9.0	5.2	3,606	**0.466**
2010	51.3	9.6	5.2	4,834	**0.500**
2011	51.7	9.7	5.5	4,940	**0.507**
2012	52.1	9.8	5.7	5,035	**0.514**
2013	52.4	10.0	5.9	5,173	**0.521**
2014	52.8	10.0	5.9	5,443	**0.525**
2015	53.1	10.0	6.0	5,443	**0.527**

Source: UNDP, 2016

An oil-rich country and a former British colony, Nigeria has, over the years, played significant roles within the African continent and the global arena. Nigeria is a signatory to several sustainability-related treaties including Kyoto Protocol, Basel Convention, Stockholm Convention and Abuja Sustainability Declaration amongst several others. The performance of Nigeria on the sustainable development dashboard of 2016 varied across the indicators ranging from being in the top third category to being amongst the bottom third performers (UNDP, 2016). In particular, Nigeria is grouped in the bottom third category for renewable energy consumption, external debt stock, population in multidimensional poverty and government's spending on research and development. The country is in the top third category in terms of change in forest area, old age dependency ratio, and freshwater withdrawals. Nigeria's performance is categorised under the middle third group for carbon dioxide emission per capita and adjusted net savings. Largely, Nigeria is ranked 141 out of 149 countries on the SDG Index (Sachs *et al.*, 2016).

As a vibrantly developing economy, Nigeria relentlessly engages in engineering and industrial activities. Since the colonial era, Nigeria has witnessed spiralling engineering infrastructural developments including the development of the Ajaokuta steel plant, establishment of crude oil refineries, construction of roads and railways, and building of houses and other civil infrastructures. These activities are generally geared towards enhancing the socioeconomic conditions of Nigerians. The country's HEIs have contributed immensely to the engineering efforts by producing engineers annually to occupy important engineering posts across the country. However, given the difficulty associated with the trade-off between socioeconomic needs and environmental consumption, engineering sustainability in Nigeria may be constrained. Therefore, to what extent is sustainability instruction part of the Nigerian engineering education becomes a pertinent question. With its ratification of several sustainability pacts, it is imperative to evaluate the consideration of these pledges in the Nigerian engineering curriculum.

Engineering in Nigeria

Like many of its other tools of modernity, engineering in Nigeria evolved as a necessary outcome of colonialism. Engineering activities were undertaken to facilitate and advance the goals of colonial government centred around governing Nigerian territories to expand commerce and promote progress and civilisation (Falola and Heaton, 2008). Accordingly, road and railroad construction, provision of water supply, waste management, mining, dredging, housing, electrical and mechanical works featured prominently amongst recurrent engineering projects in colonial Nigeria. The establishment of Public Works Department (PWD) by the southern Lagos government in 1896 institutionalised engineering practice in the colony (Ojiako, 1986). PWD Lagos, which comprised three units, namely civil, mechanical and electrical, was tasked with addressing engineering problems in the colonial region. Similar PWD outfits were established by the other regional governments of Northern and Eastern Nigeria after independence in 1960.

The engineering legacy bequeathed to Nigeria by the British continued without much change. Indigenisation efforts progressed very slowly as British and other foreign engineers continued to direct various engineering works across the country. Over the years, Nigeria began to take full ownership of engineering practice in the country. Professional associations emerged including Nigerian Society of Engineers (NSE), Council for the Regulation of Engineering in Nigeria (COREN), and the Nigerian Academy of Engineering (NAE). These bodies severally acted as consultants to successive Nigerian governments and to the academia broadening the purview of engineering knowledge and ensuring professionalism. Engineering practice in Nigeria currently occurs within the structure of governmental regulation and professional associations’ guidance. Only registered engineers are permitted by law to practice engineering in Nigeria. Presently, there are some 30 engineering fields approved and practised in Nigeria (BMAS, 2014).

Education in Nigeria

Education in Nigeria has had a chequered history. Depending on the chronological thinking adopted, Nigeria's educational history has been traced to as far back as the appearance of Nok culture circa 1000BCE. Archaeological finds of the Nok civilisation such as Louvre (Figure 3.2) and Rider and Horse (Figure 3.3) are presented as partial evidence of Nok people's informal and familial system of knowledge transfer. Such model is said to have endured for millennia amongst the various ethno-nations that eventually formed present-day Nigeria. Other historical sources not given to grandiose metanarratives begin the story of Nigeria's education in the early 19th century with the arrival of Christian missionaries. This version refers to English classes held at the palaces of chiefs or *obas* with the sole aim of proselytising locals as the roots of Nigerian educational system. These classes later expanded into full blown schools teaching other Western educational subjects. Aided by colonial government, Christian missionary schools were continually established across the southern region until Nigeria gained independence in 1960.

Figure 3.2. Nok Terracotta Louvre

Figure 3.3. Nok Rider & Horse

Regardless of the historical lens employed, Nigeria, in the wake of its independence from Britain, had an educational system modelled on the English framework. Since the 1960s, successive Nigerian administrations have made efforts to modify the colonial educational legacy for effective and meaningful outcomes. The country went from the year-based 7-5-2-3 system[25] in 1960 to 6-3-3-4 system[26] in 1977. The 9-3-4 system[27]

[25] Seven years of primary, 5 years of secondary, 2 years of post-secondary, and 3 years of university education.
[26] Six years of primary, 3 years of junior secondary, 3 years of senior secondary and 4 years of tertiary education.
[27] Universal Basic Education; free education in the first 9 schooling years, then 3 & 4 years of secondary and tertiary education.

was introduced in 1998 sequel to the revision of National Policy on Education (NPE). HEIs grew from only two technical colleges in 1944 to a total of 160 in 2018, comprising 40 federal universities, 46 state universities and 74 private universities (NUC, 2018). Several engineering programmes are offered in most of these HEIs. Today, Nigeria's Federal Ministry of Education (FME) has the mandate to formulate, coordinate and oversee enactment of national educational policies. The current educational system in Nigeria consisting of basic primary education, junior secondary education, and senior secondary and tertiary education is depicted in Figure 3.4.

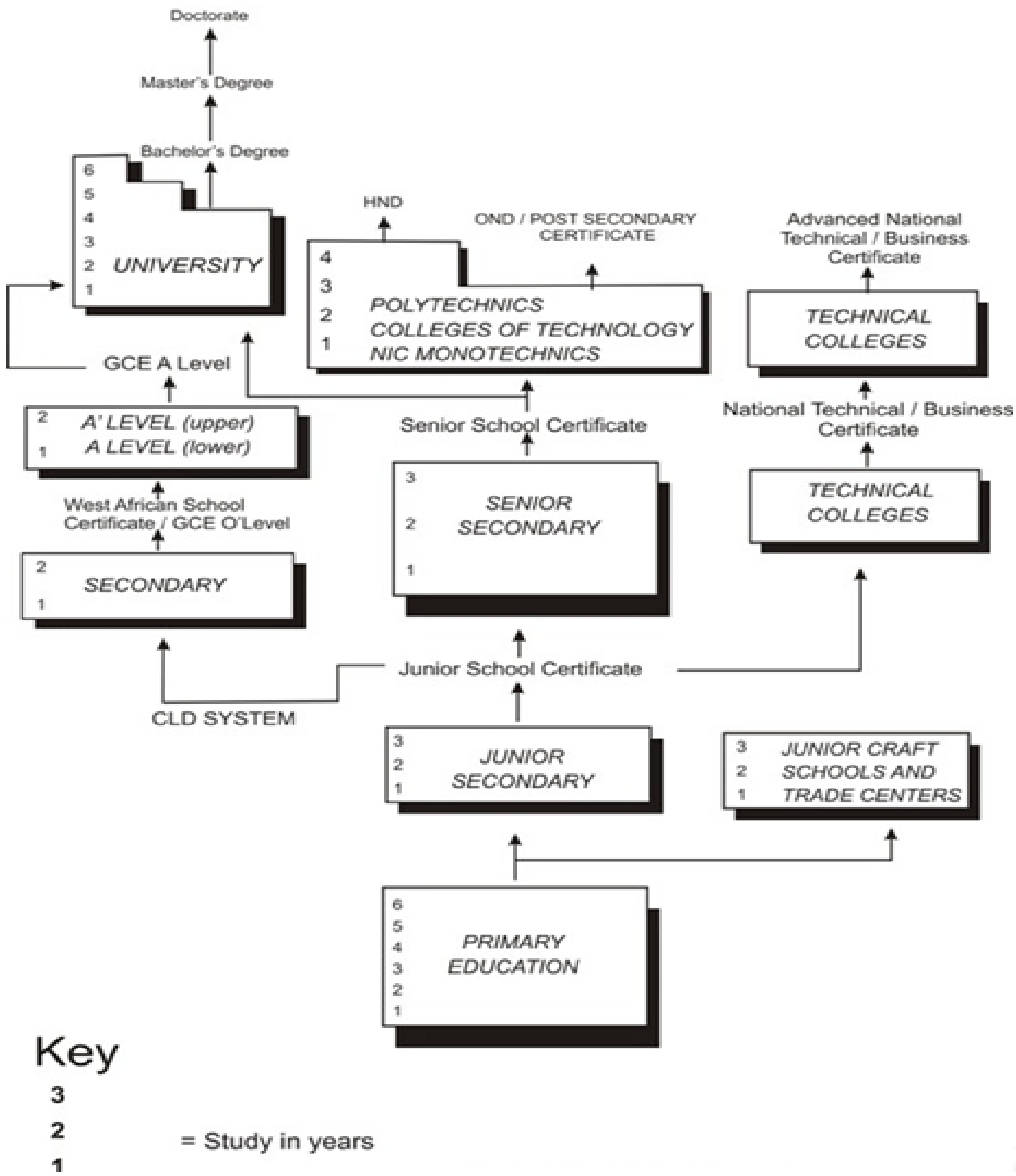


Figure 3.4. **Educational system and qualification structure in Nigeria** (FME, 2016)

Educating Nigerian Engineers

The pathway to a professional engineering career in Nigeria begins with a university degree. Initial move towards educating Nigerians in the technical field was in the form of two technical colleges of Yaba Technical Institute (now Yaba College Technology) and Technical Institute Kaduna (now Kaduna Polytechnic) established in 1948 and 1958 respectively. However, engineering education in the modern sense debuted in Nigeria in 1961 when College of Engineering, (now Faculty of Engineering) was created at the newly established University of Nigeria Nsukka (UNN) in Enugu. Other engineering faculties were subsequently established in 1962 at University College Ibadan, now University of Ibadan (UI), and Ahmadu Bello University (ABU) Zaria. These efforts to educate indigenous engineers who had hitherto been trained overseas added complexity to an incipient educational system.

Educational policies episodically formulated by FME contributed in shaping the route to an engineering career. Students desiring to study any engineering field are required to take such science subjects as mathematics, physics, and chemistry at senior secondary level. A minimum of credit score in these subjects and in two others including English Language at the West African Examination Council-conducted examinations or the national equivalent is mandatory. Initially modelled on the British system that operates a 3-year engineering programme, engineering degree in Nigeria is now acquired over a 5-year period. General physical and chemical science subjects accompanied by one or two social science subjects including Use of English are taught to first- and second-year engineering students. Students are progressively exposed to the core of their chosen disciplines over the next three years.

A compulsory industrial work experience scheme is sandwiched in the engineering programme. In the final year of their programme, engineering students undertake a research project either individually or collaboratively under the supervision of an academic. A Bachelor of Engineering or Bachelor of Technology in Engineering is typically awarded upon a successful completion of the 5-year programme. Engineering education in Nigeria has, however, been often criticised for producing unemployable graduates. Some of the reasons usually adduced for this undesirable outcome include disproportionate theoretical content, lack of funding, poor curriculum development, inadequate staff and inexpert teaching.

The theoretical content of the Nigerian engineering curriculum is considered higher than its practical element. As a colonial legacy that has not been significantly modified, the engineering curriculum in Nigeria retains a disproportionate amount of conceptual engineering sciences subjects. The attempt to correct this aberration through the mandatory industrial work training has not yielded the desired effect as student placement opportunities are scarce. Despite the fact that engineering activities are continuously undertaken across the country, Nigeria is largely unindustrialised, which limits the industrial training chances of the engineering students. A way around this constraint is a governmental policy that compels all engineering contracting firms operating in Nigeria to provide internship to the students. Additionally, it would be imperative to review the dominant teacher-centred pedagogy by introducing some of the various forms of enquiry-based learning.

An oft-repeated challenge of engineering education in Nigeria is inadequate funding. This problem is, however, not unique to the Nigerian engineering education. Generally, the funding of education in Nigeria has been poor (Akinsanya, 2013). Although the UNESCO recommends the devotion of at least 15-20% of annual public resources to education (UNESCO, 2015), the Nigerian government has hardly ever exceeded 12% of its yearly expenditure on education (Mathew, 2016). Such budgetary allocation is insufficient for the provision of quality education in a country with no less than 160 universities (NUC, 2018). The delivery of a praxis-oriented engineering education in Nigeria requires the provision of standard engineering laboratories as well as servicing the opportunity cost of labour, such as salaries and allowances.

Inadequate staffing also constrains the provision of high quality engineering education in Nigeria. The stipulated student-staff ratio for any engineering programme in Nigeria is 15:1 (BMAS, 2014). However, studies have shown that the majority of engineering education institutions across the country do not fulfil this requirement (Afonja *et al.*, 2005; Onwuka, 2009; Akintola *et al*., 2016). There are instances in which a university exceeded the stipulated ratio by a factor of four (Saint *et al.*, 2003). Related to staffing problem is the issue of inexpert teaching. The challenges of inadequate staff and inexpert teaching are a fallout of poor funding. With sufficient financial resources available to higher education, more staff can be employed. Furthermore, educator training through participation in teacher training courses, doctoral programmes, and international conferences can be undertaken more frequently.

Sustainability Issues in Nigeria

Nigeria's interest in sustainability-related issues was piqued by an environmental disaster in 1987. In the wet season of that year, it became evident that about 4000 tonnes of toxic waste originated from Italy had been dumped in Koko, Delta State. The Koko incident prompted the enactment of Federal Environmental Protection Agency (FEPA) Decree and the Harmful Waste Decree in 1988. The Harmful Waste Act proscribed dumping and trafficking in toxic wastes across Nigerian territorial boundaries including its Exclusive Economic Zone (EEZ). The FEPA Decree led to the formation of Nigeria's environmental agency tasked with the overall protection and management of the environment. In 1999, the Federal Ministry of Environment (FMEnv) was established to coordinate all environmental matters including the episodic draft of National Environmental Policy (NEP). FEPA, which metamorphosed into National Environmental Standards and Regulations Enforcement Agency (NESREA) in 2007, was subsumed by FMEnv. With a vision "to ensure a Nigeria that develops in harmony with the environment", FMEnv has since inception been active in a number of sustainable development efforts (FMEnv, 2016).

Although Nigeria does not yet have an exclusive policy on sustainable development, it, nevertheless, encapsulates some sustainability ideals within its NEP. In the preamble of the 1999 FMEnv-drafted NEP, the principle of intergenerational equity is not only stated as an underlying philosophy but expatiated by a verbatim quotation of the Brundtland sustainable development definition (FMEnv, 1999). Similarly, sustainability-related promulgations and regulations have steadily been issued to cover diverse themes such as Endangered Species Act 2004, EIA Act 2004, and Mineral Oil Safety Regulations. Others are Guidelines on Pesticides Management, Ozone Layer Protection Regulations, Solid Waste Management Policy and National Policy Guidelines on Food Sanitation. Currently, Domestication of the Kyoto Protocol, Climate Change Agency, Forestry and Review of the Ozone Depleting Substances (ODS) Bills are being processed by the Federal Ministry of Justice (FMEnv, 2016). It is instructive to note that these regulations are skewed towards the environmental dimension of sustainability.

Sustainable development concerns in Nigeria have followed the typical sustainability ideas' pattern of percolation into societies in which social and economic dimensions are preceded by the environmental component. This, perhaps, accounts for the emphasis of environmental sustainability in the NEP and other national regulations. Nonetheless, following its participation at UNCED 1992 in Rio de Janeiro, Nigeria attempted to implement the outcome of the summit by drafting Nigeria's Agenda 21. Guided by the proposals of the Earth Summit, Nigeria's Agenda 21 contextualised such sustainable development ideals as provision of sustainable human settlements and poverty alleviation which correspond to social and economic sustainability. In response to the emergence of MDGs in 2000 which amongst other equally important goals set to eradicate extreme poverty and hunger within 15 years, Nigeria created the Office of the Senior Special Assistant to the President on MDGs (OSSAP-MDGs). The OSSAP-MDGs was charged with liaison, implementation and coordination of the global millennium development agenda as well as supervision of MDG-related projects across the country (Uneze *et al.*, 2016).

The expiration of MDGs in 2015 ushered in the UN 2030 Agenda for Sustainable Development comprising 17 Sustainable Development Goals (SDGs). Nigeria was one of the 193 UN member states that endorsed the SDGs. However, concrete measures to attain these ambitious developmental goals are yet to be implemented in Nigeria. Interestingly, the performance of Nigeria on the superannuated MDGs has been assessed as unimpressive by various independent studies (WGI, 2014; Uneze *et al.*, 2016). Given the abysmal outcome of Nigeria's MDGs efforts, speculations are rife that the SDGs may not fare any better. Some critical factors arguably responsible for the country's poor performance on the MDGs include inadequate funding, poor governance and weak institutions, and insufficient technological capacity (Uneze *et al*., 2016). Blame has also been laid on the failure of the Nigerian government to design a holistic policy and institutional framework that will merge extant planning agencies and offices. National SDGs agenda call for the creation of a single government agency under which extant planning agencies and offices must be subsumed.

Sustainability Education in Nigeria

Following the pattern of its sustainability experience, Nigerian sustainability education arose in the form of environmental education. This has remained the dominant conception of sustainability education in Nigeria. The mention of education in several sustainable development-related documents such as Nigeria's Agenda 21, NEP and

Nigeria Vision 20:2020[28] is either in reference to “education for all” or to an environmental education. Given such impression of sustainability education, Nigerian educational system has responded with chiefly environment-related courses and instructions. Lessons on such environmental subjects as natural resources, public health economics, environmental sanitation, and pollution amongst several others permeate primary educational curricula. In the secondary schools, students are introduced to more advanced environmental issues including waste and land pollution, climate change, ecology and water pollution.

The permeation of environmental education into HEIs in Nigeria engendered a number of professional degree programmes with *Environmental Engineering*, *Environmental Management, Environmental Technology* and *Environmental Resources Management* covered within engineering education. Sixteen Nigerian universities presently offer these courses (JAMB, 2017). Sustainability education in the form of ESD or EESD has not gained much recognition in the Nigerian educational system. In spite of its ratification of the 2009 Abuja Declaration which sought mainstreaming sustainability education into African HEIs, Nigeria has no explicit sustainable higher education framework. There is apparently no Nigerian HEI that offers a strictly sustainability degree, course or module[29]. This absence of purposefully designed sustainability programmes in Nigerian HEIs has also been suggested by MESA study in 2004 and UNDESD *Final Report* in 2014. MESA conducted a baseline study in several African countries including Nigeria and concluded that sustainability education “was slow to evolve in Africa” owing to the continent’s other countless post-colonial challenges (Thakran, 2004). UNDESD *Final Report* suggests that “sustainable development is only an emerging interest among African HEIs” (UNESCO, 2014).

The prospect of an accelerated uptake of context-relevant sustainability education in Nigeria has equally not been realised even with the existence of UN-established Regional Centres of Expertise (RCE) on ESD. Developed following the start of UNDESD in 2005, the concept of RCE features formal, non-formal, and informal educational systems in the promotion of ESD. In Nigeria, RCEs are located in Kano, Minna, Port-Harcourt and Lagos. Although appreciable progress has been made in

[28] An economic transformation blueprint prepared in 2009 by the National Planning Commission articulating development strategies to position Nigeria among the 20 largest economies in the world by 2020.
[29] This is based on the JAMB Brochure which contains all the courses offered in Nigerian HEIs.

terms of the informal and non-formal components of ESD by the RCEs, the formal element is inadequately attended to. Contributing to this undesirability is the failure of the RCEs to successfully network with Nigerian HEIs thereby fragmenting the ESD initiative. Renewed networking efforts are required to mainstream sustainability education into HEIs in Nigeria. An important means of achieving such nexus is through FME, FMEnv and other HEIs stakeholders including COREN and National Universities Commission.

Summary

Engineering education and sustainability in Nigeria are as yet not properly aligned. Engineering has been practised in Nigeria since the colonial era manifest in road and railroad construction, dredging, and water supply amongst others to facilitate imperial expansionism. At independence in 1960, Nigeria inherited an educational system modelled on the British standard within which emerged its engineering education framework. Little has changed about the Nigerian engineering education model. The imperative of sustainability education suggests a complex dimension for Nigerian engineering education. In spite of being a signatory to several sustainability pacts and the experience of an environmental disaster, Nigeria’s response to sustainability is somewhat inchoate.

This chapter discussed the Nigerian sustainability experience and how the country’s responses have failed to permeate the HEIs especially engineering programmes. It pointed out that even though some thirty engineering fields are presently practised and taught in Nigeria, less than five courses are environmental studies. Sustainability education in the form of ESD/EESD is virtually non-existent in Nigerian HEIs. The chapter stressed the findings of MESA study and UNDESD report as corroboratory evidence of the slow uptake of ESD/EESD in Nigeria. The need to galvanise HEIs stakeholders by the RCEs was emphasised. Generally, the chapter presented an important argument for the present study.

Chapter Four

4 Research Methodology

Introduction

This chapter sets out the overall methodological framework for the present research. It recaps the research questions and discusses sustainability assessment approaches vis-à-vis sustainability content, sustainability literacy and sustainability learning process. The chapter then highlights the research approach, research paradigm and research design used in the study. Thereafter, methods of data collection and data analysis are addressed before considering the validity, reliability, and ethical issues of the study.

Research Questions

1. What is the current level of sustainability knowledge of the Nigerian engineering community?

2. What is the sustainability content of the Nigerian engineering curriculum?

3. What sustainability education interventions are appropriate for the Nigerian engineering curriculum?

The methodology for addressing the above research questions benefited from the emerging studies of sustainability assessment in higher education. The next section presents a review of approaches in assessing sustainability education in HEIs.

Assessing Sustainability Education

Sustainability assessment has been undertaken since the emergence of sustainability. Across different organisations, assessment tools have been developed to evaluate various sustainability initiatives. In higher education, sustainability assessments have generally focused on the customary HEI functions of education, research, community outreach, and university operation (Lozano and Lozano, 2014). The education component of these evaluations usually features curricular assessments vis-a-vis sustainability content, sustainability literacy, and sustainability learning process.

Sustainability Content

The assessment of a curriculum for sustainability content has usually been conducted as part of a systematic evaluation with the aid of methodical assessment tools or administration of a stakeholder survey. However, what qualifies as sustainability content is not readily intelligible as the concept of sustainability itself is highly fluid as already established in the literature. Nonetheless, the point of departure for most sustainability evaluators is the use of expert-derived sustainability themes. Some of the theme-based assessment tools that have been developed by various researchers include the Auditing Instrument for Sustainability in Higher Education (AISHE), Assessing Responsibility In Sustainable Education (ARISE), Graphical Assessment for Sustainability in Universities (GASU), and Sustainability Tool for Assessing Universities Curricula Holistically (STAUNCH).

AISHE is an assessment tool that was originally developed by the Dutch Committee on Sustainable Higher Education. The first version of the instrument designed in 2001 was reviewed in 2012 into AISHE 2012 by a HEI certification organisation dubbed Hobéon (Caeiro *et al.*, 2013). The AISHE 2012 framework is made up of four categories, namely objectives, people and resources, education, and results (see Appendix I). Sustainability assessments in HEIs based on AISHE 2012 are premised on these four categories across five stages of development, namely activity-oriented, process-oriented, system-oriented, chain-oriented, and society-oriented phases. The outcome of an AISHE 2012 audit is typically a verdict on the level of sustainability integration in an educational institution (Caeiro *et al.*, 2013). The process of an AISHE 2012 audit is consensus-building and involves a programme representative group with at least two AISHE auditors. The focus of the instrument on a single educational programme, abstract criteria and its dependence on representative groups are cited as drawbacks (Shriberg, 2002). Assessment of curricular sustainability content in AISHE 2012 is covered under the education module and is basically a subjective criterion-based process.

ARISE seeks to evaluate the sustainability and social responsibilities of HEIs. It is an instrument developed in response to educational institutions' need to manage and assess sustainability issues holistically. Hence, the purview of the ARISE tool is organisational typically covering an entire institution (Caeiro *et al.*, 2013). Eleven themes featured in the ARISE instrument include vision and mission, policy, education, research, and service to society (see Appendix II). Others are operations/planet, operations/people, operations/prosperity, students, professional field, and culture (Caeiro *et al.*, 2013). These subjects are based on the international guideline for social responsibility of organisations, ISO 26000. ARISE audit proceeds with a documentary scrutiny by an appointed audit panel which undertakes site visits. Three possible outcomes of an ARISE assessment are “committed”, “recognised”, and “excellent”, which describe the stage of a sustainability initiative in an educational institution. The education element of ARISE assesses the sustainability content of a curriculum in an inexplicit manner deferring to the audit panel's impression on some generic statements. This is considered a deficiency of the ARISE assessment tool.

GASU (see Appendix III) was developed as a modification of the Global Reporting Initiative Sustainability Guidelines intended to guide environmental, economic and social performance of organisations (Lozano, 2006). GASU aimed to adapt these guidelines for use in HEIs by adding an educational dimension. GASU is a graph-based assessment tool that facilitates the comparison of sustainability efforts between educational institutions. The instrument makes use of indicators scaled from 0 to 4 to automatically generate nine charts across the three sustainability pillars (environment, economy, and society) and the additional educational dimension (Lozano, 2006). The strength of GASU in being an indicator-based tool benefits organisations by ensuring consistency, which is vital for comparison and benchmarking. Nonetheless, the evaluation of sustainability content of a curriculum with the GASU instrument is not without limitations due to the added complexity of the educational dimension. To accommodate the educational component certain curricular-relevant themes such as competency and learning outcomes have been overlooked.

STAUNCH® (Sustainability Tool for Assessing Universities Curricula Holistically) is an education assessment tool developed in 2007 to benchmark the extent of a university curriculum's coverage of sustainability ideas (Lozano and Lozano, 2014). STAUNCH® analyses sustainability content of curricula by examining syllabi or course descriptors (including course aims and outlines) as data source based on 40 sustainability topics across economic, social, environmental and crosscutting dimensions. This implies that result accuracies are contingent on the credibility of the course information available and that unpublished course information cannot be captured. Nonetheless, the assessment tool has proved quite useful in sustainability education research in a growing number of HEIs including all universities in Wales and two universities in England[30]. An important strength of the STAUNCH® tool is its focus on the curriculum.

An operational definition of sustainability content adopted in the present study is *the spread or coverage of sustainability topics or themes in a curriculum stressing the interconnection of environment, economy, and society along with the multidimensional problem-solving strategies for addressing sustainability challenges*. None of the reviewed sustainability assessment tools perfectly matches this working definition excepting the STAUNCH®. The sustainability topics featured in the STAUNCH® tool seem adaptable for the purposes of the present study in line with the above operational definition.

[30] http://org-sustainability.com/eng/staunch

Sustainability Literacy

Sustainability literacy has been defined variously in the literature. A number of scholars delineate sustainability literacy in terms of "skills, attitudes, competences, dispositions and values" necessary for delivering a sustainable world (Stibbe, 2010). The global non-profit consultancy, *Forum for the Future*, explains that a sustainability literate person should "understand the need for change to a sustainable way of doing things, individually and collectively". Furthermore, such a person should "have sufficient knowledge and skills to decide and act in a way that favours sustainable development". Further, sustainability literacy should enable one "to recognise and reward other people's decisions and actions that favour sustainable development" (Parkin *et al.*, 2004, p.9). Another contribution to the definitional question of sustainability literacy describes it as "knowledge, skills and understanding required to fashion a more sustainable future" (Vare and Blewitt, 2010). Definitions of sustainability literacy emphasise both knowledge and skills. However, the most common instrument employed to test sustainability literacy is in the form of a quiz and focus on knowledge.

Most sustainability literacy tests feature a set of multiple choice questions as typified in the *Assessment of Sustainability Knowledge* (ASK) developed by the Ohio State University in conjunction with the University of Maryland (Zwickle *et al.*, 2013). ASK contains 16 multiple choice questions about wide-ranging global sustainability issues as well as matters of contextual relevance to the United States. An important distinction of the ASK instrument is its focus on factual knowledge as opposed to beliefs and values. The questions on ASK are expert-derived involving contributions of academics from various disciplines. For its several utilisations, the instrument was deployed online aided by the SurveyMonkey software package (Zwickle *et al.*, 2014). Some constraints of the ASK tool are related to the conventional limitations of multiple choice questions and the inapplicability of the tool in other national contexts. Also, the ASK instrument assesses foundational knowledge and not necessarily literacy at the levels of analysis, synthesis, and evaluation.

An effort to evaluate sustainability knowledge worldwide yielded the first international sustainability literacy test dubbed *The Sulitest* (Carteron and Decamps, 2017). The Sulitest is an online multiple choice questionnaire divided into three modules: core, specialised (and customised), and surveys (Figure 4.1). The core module features 30 questions of common relevance to all countries, whilst 20 questions are contained in the specialised module covering national, regional, and cultural contexts. Provision is made in the customised module to allow organisations or firms set context-relevant questions. An optional anonymous survey is appended at the end of each session to gather demographic information and ask sustainability education questions. The development of the Sulitest benefited from inputs of reputed sources in the sustainability research community. The tool is supported by the UN and has so far been used by at least 612 educational institutions from around the world (Sulitest, 2016). To partake in the test, an institution must register on the Sulitest website and appoint a representative known as the Focal Point. An examiner is also chosen by the institution to set the customised questions. Students can only take the test after accessing a code generated by the examiner. Some limitations of Sulitest commonly cited are questionnaire length, overrepresentation of some countries, and inherent constraints of multiple choice questions.

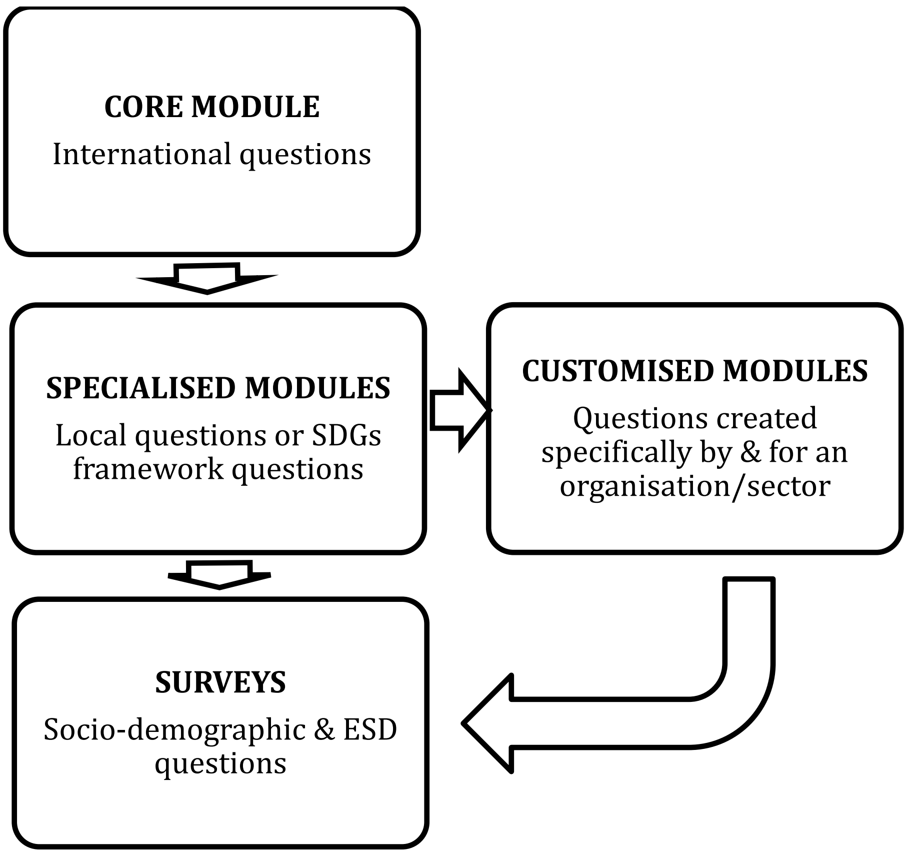


Figure 4.1. The Sulitest
Source: Cateron and Decamps, 2017

Sustainability Learning Process

Sustainability learning process, as reviewed in *Chapter Two*, features numerous pedagogical techniques including lecturing and a variety of enquiry-based learning approaches, such as PBL, PjBL, and case-study. Jowitt (2004) argues that given the well-known pressures on engineering curriculum, the focus of sustainability education should be on the learning process and not necessarily on the content. The crux of Jowitt's argument is that sustainability is consistent with systems thinking and should, therefore, be mainstreamed into engineering education targeting the "inculcation of an appropriate habit of mind, attitudes, and systems skills" (p.87). To produce protean and sustainability literate engineers of the future, the engineering learning process must be amenable to the use of case-studies, studio-based, issue-driven, process-based, team-based, and design/delivery focused (Jowitt, 2004). However, Jowitt concedes that the use of these enquiry-based learning methods could be augmented with some content that will aid the development of appropriate levels of awareness, skills and knowledge.

In terms of sustainability awareness, Jowitt explains that the objective is to develop an orientation to engineering problems in the context of environmental, economic and social issues. The skills component should cover collaborative abilities as well as an ability to assess the advantages and disadvantages of alternatives and to deal with complex and ill-defined problems. The characteristics of the knowledge aspect are broadness, depth, and technicality amongst others (ThinkUp, 2011). An interesting way the enquiry-based learning approach can be utilised in a sustainability education research is through a workshop. Workshop typically involves an ensemble of people gathered to learn, acquire new knowledge or undertake an innovative problem-solving (Ørngreen and Levinsen, 2017). Workshop allows the trial of numerous teaching techniques ranging from lecturing to case-study. The research methodology of the present study benefited from the imperativeness of process in sustainability education through the employment of a workshop.

Research Approach

A research approach delineates the modes and procedures employed in the conduct of research detailing ways and methods of data collection, analysis and interpretation

(Creswell, 2014). Three research approaches distinguished in academic research discourse are quantitative, qualitative and mixed approaches. A substantial body of literature has been devoted to explaining these approaches. In the present study, the mixed methods research was adopted.

Quantitative Research

In the quantitative approach, a research problem is understood or explained deductively, i.e. the research process ends with a confirmation or disproof of a theory or hypothesis. The main characteristics of the quantitative approach are deduction, confirmation, and theory/hypothesis testing amongst others (Johnson and Onwuegbuzie, 2004). Quantitative research is common in the physical sciences. The philosophical assumption usually associated with the quantitative approach is positivism or post-positivism, which underpins the conventional scientific approach. Reality is assumed to exist “out there” in the world and can be numerically measured and studied. Such an approach is reductionist. Positivist researchers strive to eliminate biases and apply conscientious efforts to detach themselves from the studied or observed phenomenon. In the current study, quantitative data involved closed-ended surveys, content analysis, and a customised sustainability literacy test.

Qualitative Research

The qualitative approach to research is traditionally associated with the humanities and social sciences. As a research approach, it seeks to explore and understand a research problem or phenomenon inductively, i.e. generating theory only at the end of the research process. The key characteristics of the qualitative approach are induction, discovery, and theory/hypothesis generation amongst others (Johnson and Onwuegbuzie, 2004). The philosophical underpinnings of the qualitative approach are typically constructivism, interpretivism, and transformative worldview. Knowledge according to these schools of thought is socially constructed. The transformative paradigm extends the constructivist stance by seeking to examine individual experiences of oppression or other unpleasant social phenomenon and developing an action plan or agenda for liberation. Scenarios in which qualitative research can be useful include examination of an entirely new subject, investigation in an unexplored context, and situations of inapplicable extant theories or knowledge (Creswell, 2014).

The qualitative data collected in the present study involved open-ended questionnaire and workshops.

Mixed Methods Approach

For many decades, qualitative and quantitative research methodologies dominated the discourse of academic research based on an incompatibility thesis (Howe, 1988) - the view that the two approaches are incompatible and should therefore not be conflated. In the 1980s and 1990s, movements emerged challenging the rationale for the rigid stance adopted by proponents of qualitative and quantitative approaches. These advocacies did not only call for the mixing of the research approaches but also integrated them in actual research. The outcome of these efforts is the mixed-methods research approach. Mixed methods research is defined as “an approach to inquiry involving collecting both quantitative and qualitative data” which are then integrated using discrete designs premised on the pragmatist philosophical and theoretical assumptions (Creswell, 2014, p.4). The impetus for the rise of the mixed methods research is the potential of the approach to combine the strengths inherent in both quantitative and qualitative approaches. A more comprehensive understanding of a research problem or question is believed to result from the mixed methods approach. Although several terms have been used to describe this approach such as multimethod, mixed methodology, synthesis approach, and hybrid method, mixed method research or mixed research are the most widely accepted and have been used interchangeably in this study.

Rationale for Selection of Mixed Research Approach

The choice of mixed research to conduct the present study was informed by several reasons, which revolved around the research questions. The central query of the research raised the question of what sustainability education interventions were appropriate for the Nigerian engineering curriculum. Critical to answering this question was knowledge about the sustainability literacy of the Nigerian engineering community as represented by practitioners, educators and students as well as an assessment of the sustainability content of the Nigerian engineering curriculum. Whilst some of these questions suited the quantitative method, others required a qualitative approach. For instance, a quantitative approach involving the use of a sustainability literacy test was needed to gauge the level of sustainability knowledge of Nigerian engineers and students. Similarly, since the study sought to generally investigate a phenomenon (sustainability education) in an unexplored context (Nigerian engineering education), the qualitative component of the mixed research was invaluable. In addition, the mixed research approach was chosen based on its non-limiting and eclectic quality which allowed for practical and creative research designs. Hence, a bespoke research design and plan was developed in such a way as to result in credible and beneficial answers.

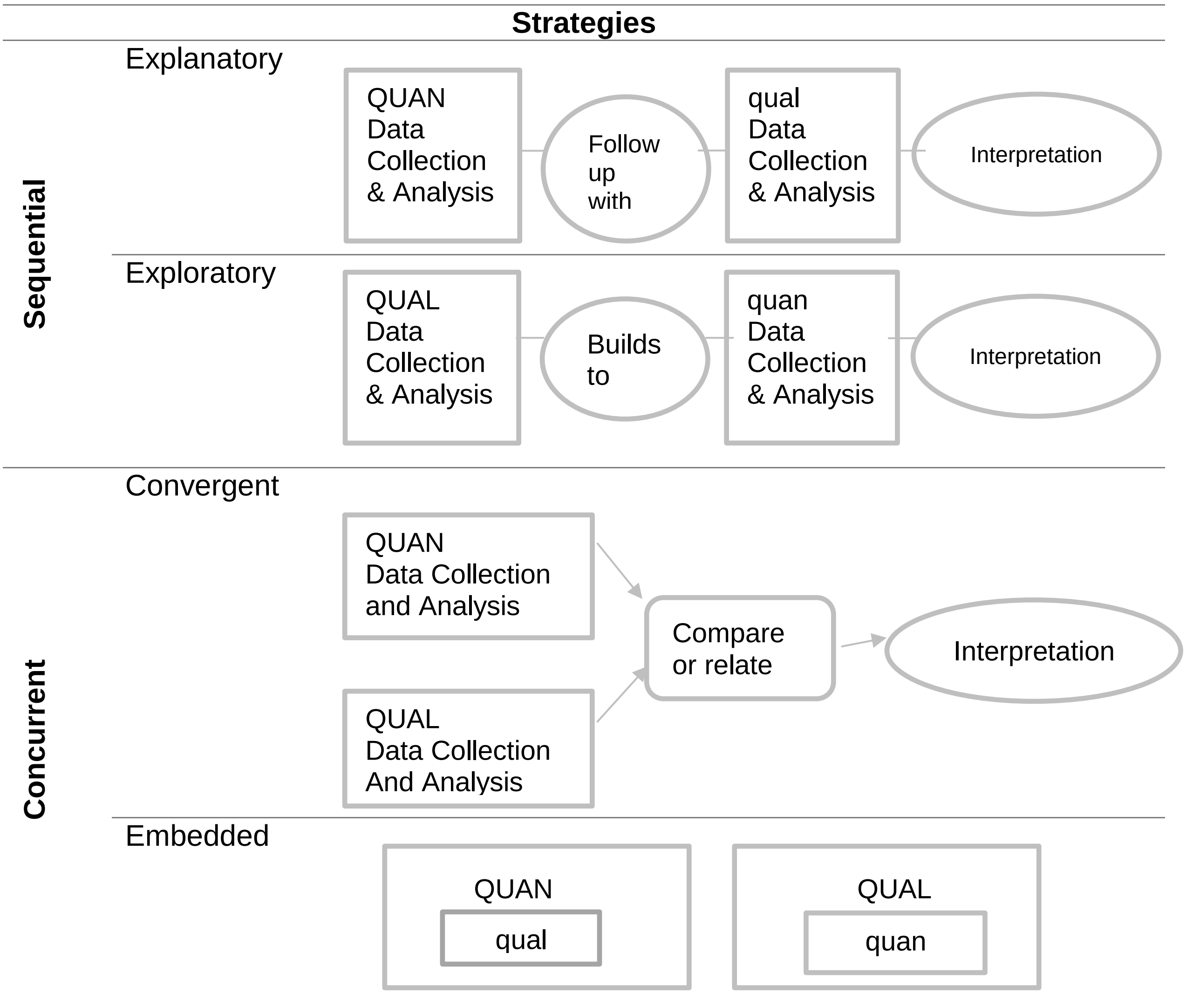
Research Paradigm

Pragmatism is the research philosophy or worldview linked with the mixed research. This study, having adopted the mixed research approach, espoused the pragmatic worldview. Pragmatism is a philosophical tradition that gained prominence in the latter part of the 19th century through the efforts of such philosophers as Charles Sanders Peirce, William James and John Dewey (Hookway, 2016). The pragmatist agenda aptly termed *pragmatic maxim* is based on the rule that the contents of hypotheses (or truth value of an expression) are contingent on their practical consequences. Knowledge in the view of pragmatists is both objective reality (positivism) and social construction (constructivism) and can be derived eclectically using any means practicable. An important hallmark of the pragmatic worldview is pluralism, which endorses the potency of various approaches to knowledge without commitment to any one particular system. The mixed research, upholding the pragmatic stance, makes it possible for researchers to utilise qualitative and quantitative approaches liberally drawing on the approaches' philosophical assumptions. Additionally, mixed methods researchers based on insights from pragmatism have the advantage of selecting methods and research strategies that "offer the best chance to obtain useful answers" (Johnson and Onwuegbuzie, 2004, p.15). Thus, in the pragmatic mixed-methods research approach, research questions are the most important determinant of a research methodology. The present study was guided by the pragmatist research philosophy.

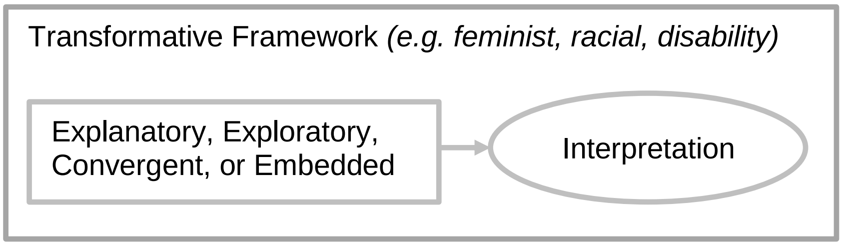
Research Design

In the conduct of mixed research, a number of strategies as illustrated in Table 4.1 have been used by researchers. The strategies basically differ according to manner of data usage, timing of data collection (concurrently or sequentially), and database emphasis (Creswell, 2014). Five of these strategies are explanatory, exploratory, convergent, embedded and transformative mixed-methods. The *explanatory sequential strategy* involves the collection and analysis of quantitative data followed by the collection and analysis of qualitative data. The overall aim of this strategy is to use qualitative data to further explain an initially analysed quantitative data. The hallmark of this approach is that the quantitative component is given priority over the qualitative element; hence the QUAN and qual notations.

Table 4.1. Mixed research strategies (Creswell, 2014)



Transformative



The *exploratory sequential strategy* is simply the reverse of the explanatory strategy. Qualitative data collection and analysis precede quantitative data collection and analysis. The object of the exploratory strategy is to build qualitative results into the quantitative phase to facilitate generalisation of findings. Priority is usually given to the qualitative component of the mixed research; hence the QUAL and quan notations. *Convergent strategy* is perhaps the most recognisable mixed research approach. It involves concurrently collecting quantitative and qualitative data and separately analysing them. The overall aim of the convergent strategy is result (data) comparison to deepen interpretation. Ideally, both quantitative and qualitative elements are given equal priority (QUAN + QUAL), but practically either of the components can be emphasised.

The *embedded mixed strategy* is an advanced approach that nests or inserts either quantitative method within qualitative approach or vice versa. Data can be collected concurrently with the overall goal of having different levels of research addressed in a single study. The integration of collected data happens during data analysis and priority is usually assigned to the predominant method. In the *transformative mixed approach*, aspects of the explanatory sequential, exploratory sequential, convergent parallel and embedded mixed strategy are used within a transformative framework. The objective of such ensemble is to harness the potentials of mixed research strategy within a social justice framework to deliver a transformation agenda.

Selection of Embedded Mixed Research Strategy

The present study adopted the **concurrent embedded mixed research strategy** with emphasis on the quantitative component. This implied that the qualitative element was nested within a predominant quantitative research design as depicted in Figure 4.2. Such strategy proved appropriate for the purposes of the present research.

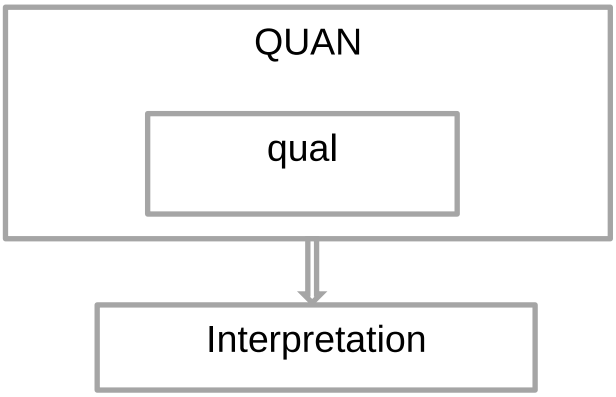


Figure 4.2. **Research strategy for present study**

Data Required

The research questions of the present study determined the data required. In order to answer the questions, data in the forms of sustainability knowledge and sustainability content were invaluable. The "knowledge" data were necessitated by the first research question: *What is the current level of sustainability knowledge of the Nigerian engineering community?* To address the question an assessment of the knowledge of the engineering community was essential. Both qualitative and quantitative data were needed for such assessment. The "content" data was required to address the second research question: *What is the sustainability content of the Nigerian engineering curriculum?* This question called for an evaluation of the Nigerian engineering curriculum in the form of documents and stakeholder perspectives. The last research question, "*What sustainability education interventions are appropriate for the Nigerian engineering curriculum?"* required textual data from literature as well as results obtained from the analysed data of the first and second research questions. These requirements collectively informed the data collection and data analysis methods in the present study.

Survey Population and Sample Size

The survey population in this research was the Nigerian engineering community which comprised engineering students, engineering educators and engineering practitioners. Although it was challenging to ascertain the population of the Nigerian engineering community, an estimated figure of 100,000 was assumed in the present study. This figure was arrived at based on the number of COREN registered engineers and on the number of engineering students and educators estimated from the guide provided by

COREN. Appendix IV presents a calculation of the estimated survey population. Using a 95% confidence level and a 5% margin of error, a sample size of 383 was calculated for the Nigerian engineering community. However, the sample size that was eventually achieved in the study was **n=442**. Of the 442 respondents, 232 were engineering students (n=232), 84 respondents were engineering educators (n=84) and 126 were engineering practitioners (n=126).

Engineering Students

Engineering students were recruited chiefly from two federally-run Nigerian HEIs anonymised in this study as HEI-1 and HEI-2. The sample size of the engineering students was **n=232**. Both HEI-1 and HEI-2 were chosen for their assorted engineering programmes, excellent academic record, cultural diversity and logistical reasons. The students in HEI-1 (n=137) were sampled from the seven engineering departments in the institution. With departmental percentages in parenthesis, the sample comprised: agricultural (9.5%), chemical (11.7%), civil (19.7%), electrical & computer (8.0%), mechanical (12.4%), metallurgical & material (26.3%), and water resources & environmental engineering (13.1%). Similarly, HEI-2 students (n=95) were derived from the institution's three departments: civil (30.5%), electrical (30.5%) and mechanical engineering (38.9%). An average of 19 engineering students from each department participated in the survey. Two categories of students targeted in the survey were postgraduate (PhD and MSc) and undergraduate students. Fourth- and final-year students were selected to represent the undergraduate category in view of their extensive experience with the Nigerian engineering curriculum. As presented in Table 4.2, the sample comprised 10 doctoral, 74 master's and 148 undergraduate students. Also, there were 40 female and 192 male students in the sample.

Table 4.2. Demography of engineering students

Category	Male (n)	Female (n)	Age range (years)	Total (n)
Graduate – Doctoral	10	-	>38	10
Graduate – Masters	62	12	27-35	74
Undergraduate – fourth & fifth year	120	28	22-24	148
Total	192	40	-	232

Engineering Educators

Eighty-four engineering educators, **n=84**, were recruited for the survey from HEI-1 and HEI-2. The sample sizes for HEI-1 and HEI-2 engineering educators were n=55 and n=29 respectively. The educators cut across the seven engineering programmes represented by the engineering students. For HEI-1 engineering educators (n=55), the percentages of the participants by department were agricultural (1.8%), chemical (29.1%), civil (7.3%), electrical & computer (40.0%), mechanical (10.9%), metallurgical & material (9.1%), and water resources & environmental engineering (1.8%). HEI-2 engineering educators (n=29) were represented thus: civil (37.9%), electrical (34.5%) and mechanical (27.6%). An average of 10 educators per engineering department participated in the study. Table 4.3 presents a demography of the sampled engineering educators. The sample consisted of 10 female and 74 male respondents with 25 bachelor's degree holders, 40 master's degree awardees, and 19 doctorate degree holders.

Table 4.3. Demography of engineering educators

Educational level	**Male (n)**	**Female (n)**	**Age range (years)**	**Total (n)**
Bachelor's degree	20	5	27-35	25
Master's degree	35	5	36-39	40
Doctorate degree	19	-	>40	19
Total	74	10	-	84

Engineering Practitioners

Engineering practitioners were recruited randomly across Nigeria. COREN and NSE provided a significant access to Nigerian engineers, which ultimately yielded a sample size of **n=126**. The engineering practitioners were of various disciplinary backgrounds including aeronautical (3.2%), aircraft (0.8%), agricultural (4.9%), chemical (11.1%), and civil engineering (24.0%). Others were computer (3.8%), electrical (29.0%), mechanical (15.9%), metallurgical (3.6%), and mining engineers (3.7%). Table 4.4 shows the demography of the sampled engineering practitioners. In terms of the employment category, 81 respondents were in the public sector, whilst 42 and three were in private and multinational employment respectively. Furthermore, the sample consisted of 121 male and only five female participants. The educational level of the sampled engineering practitioners featured 88 bachelor's degree holders, 36 master's degree awardees and two doctorate degree holders. The engineering practitioners had differing lengths of professional experience with 46 of them in the range of 0-5 years. Fifty-one had between 6-10 years of professional experience, whilst 20 had worked for 11-15 years. Only three of the sampled engineering practitioners had over 30 years' professional experience.

Table 4.4. Demography of engineering practitioners

Employment	Gender (n)		Educational level (n)			Experience (in years)						
	Male	Female	Bachelor's	Master's	Doctorate	0-5	6-10	11-15	16-20	21-25	26-30	>30
Public	76	5	58	21	2	33	30	13	3	0	1	1
Private	42	0	29	13	0	12	20	6	0	1	1	2
Multinational	3	0	1	2	0	1	1	1	0	0	0	0
Total	121	5	88	36	2	46	51	20	3	1	1	3

An interesting observation is the low number of females in the sampled engineering community. Overall, only 12% (n=55) of the sample size (n=442) was female. This is consistent with the global phenomenon of low female participation in engineering. A recent study in Nigeria discovered that the percentage of undergraduate enrolment of women in STEM fields was 32.5, whilst that of men was 67.5% (Aderemi *et al.*, 2013). The study also found that only 14% of the academic staff in STEM departments across Nigerian universities was female. Globally, the most recent statistics on women in engineering indicates that only 11% of the engineering workforce is female, with the UK having the lowest percentage in Europe at less than 10% (WES, 2018). Therefore, the low number of females in the sampled Nigerian engineering community is not a unique feature. Some of the reasons variously adduced for low female participation in engineering in Nigeria include poor mentorship, inapt guidance and counselling, and the stereotyping of engineering as a 'masculine' profession (Badekale, 2003). These issues must be addressed to reverse the trend. In any event, the underrepresentation of females in the sampled Nigerian engineering community could not have significantly influenced the outcome of the present study since no gender-biased issues were sought.

Data Collection Method

Both quantitative and qualitative data were collected in this research. The instruments used to collect quantitative data were sustainability literacy test, content analysis, and closed-ended survey. Qualitative data were gathered from open-ended survey and a workshop.

Sustainability Literacy Test

A sustainability literacy test (SLT) was used to examine the knowledge of the Nigerian engineering community. The test was designed based on several sustainability literacy assessment tools in the literature. Instruments such as ASK and Sulitest were helpful in the development of SLT for the present study (Appendix V). Full-scale adoption of the ASK was not possible as it did not only feature US-specific questions, but also had the demerit of high response burden in relation to the present study. Similarly, the Sulitest was considered unsuitable for the reasons of bureaucracy and inadequate alignment with the purposes of the present research. As established in the review of the Sulitest, registration for the test involves a somewhat complicated administrative procedure. Not only would it be difficult to convince Nigerian HEIs and engineering professional associations to register for the online test, but it was not possible in the timeframe of the present research. Furthermore, the Sulitest is more appropriate for testing higher levels of sustainability literacy as opposed to knowledge of sustainability basics targeted in the present study. Since none of the extant tools could be used unaltered for the purposes of the current study, a bespoke SLT was designed.

An important modification in the SLT was the use of *true/false/do not know* format rather than the multiple choice questions of ASK and Sulitest. This questioning style was informed by the need to optimise test duration as well as maintain test integrity. Additionally, it was important to reduce random guessing by encouraging respondents to admit a lack of knowledge where appropriate. Another alteration in the SLT was the feature of context-relevant questions focusing on Nigeria. Contextual relevance had been repeatedly recommended in the design of sustainability knowledge assessment tools in the literature (Sulitest, 2016). Fifteen questions featured on the SLT covering environmental, economic, social and crosscutting domains of sustainability. However, these domains were not visibly delineated on the SLT as the questions were mixed to avoid a modular test design. The questions were generally framed to test foundational knowledge as an aspect of sustainability literacy. Other sustainability literacy levels such as application, analysis, evaluation, skills, and disposition were not tested as the Nigerian engineering community had not been previously studied for sustainability knowledge (see *Chapter Three*). Hence, basic sustainability concepts were the topics of interest in the SLT. Both global and country-specific sustainability issues appeared equally in the four sustainability domains. A self-assessment question was appended to the SLT to gauge the perception of respondents on their sustainability knowledge.

Content Analysis

Content analysis was used to generate data from three engineering documents: the Benchmark Minimum Academic Standards for Engineering Programmes in Nigeria (BMAS), HEI-1 engineering handbook, and HEI-2 engineering handbook. Table 4.5 is a list of the programmes contained in the engineering documents.

BMAS Document

BMAS is a document issued and reviewed episodically by COREN to set out standards for running undergraduate engineering programmes in Nigeria. A 367-page document containing over 100,000 words, the BMAS lists 30 approved engineering programmes with a description of all required courses for each programme. The scope of each course details prerequisite and co-requisite topics as well as admission requirements and list of laboratory equipment. Common engineering courses are equally detailed. The document is divided into three parts including general requirements section, specific requirements subdivision and accreditation score sheet. The BMAS is an outcome of deliberations by engineering practitioners and academics in Nigeria. Deans and heads of engineering departments from Nigerian HEIs as well as COREN management are involved in the development of the document. Each Nigerian HEI submits the syllabi of its engineering programmes highlighting course contents, philosophy, and minimum facilities. A workshop is held to deliberate on these submissions.

Courses are included in the BMAS on the basis of global best practice and contextual relevance. The BMAS standardises the syllabi and becomes the official guideline for all undergraduate engineering programmes in Nigeria. The preamble of the BMAS itemises nine learning outcomes for engineering programmes. Item 6 states that “a graduate of an engineering programme accredited by COREN is expected to have *ability to consider the environment and sustainability in finding solutions to problems*” (BMAS, 2014, p.13). An interesting fact about the BMAS is that it informs all handbooks of engineering faculties in Nigerian HEIs. Furthermore, Nigerian HEIs refer to the BMAS for purposes of accreditation and curricular development. The BMAS is the basis upon which COREN accredits engineering programmes. The mention of sustainability as a competence expected of engineering graduates is, therefore, reassuring. However, this can only be effective with an actual integration of sustainability education in the programmes. The BMAS documentary analysis set out to discover if such alignment existed.

HEI-1 and HEI-2 Engineering Handbooks

Nigerian HEIs typically maintain engineering handbooks modelled on the BMAS document to guide the running of engineering programmes in the institutions. HEI-1 and HEI-2 engineering handbooks were obtained from the two Nigerian education institutions that participated in the present study. Both engineering handbooks provide details of the various engineering programmes in the HEIs. Whilst HEI-1 details nine engineering fields, HEI-2 particularises three engineering courses. The engineering handbooks contain information on admission requirements, student workload, grading system, course title, course description and course content. Information on various topics covered under each course is equally provided in the engineering handbooks. The handbooks are customarily designed and reviewed periodically by engineering faculties based on departmental inputs. A faculty administrator collates the inputs and prepares a draft to be deliberated on at a faculty meeting. The terms of reference for the meeting include the COREN-issued BMAS document. Final approval for the engineering handbooks is granted by the faculty dean. Hard copies of the documents are normally distributed to students, whilst soft copies are uploaded to faculty websites. The HEI-1 and HEI-2 engineering handbooks used in the present study were downloaded from the websites of the education institutions.

Table 4.5. Programmes in the engineering documents

BMAS Document (n=30)	**HEI-1 Engineering Handbook** (n=9)	**HEI-2 Engineering Handbook** (n=3)
Aerospace, Agricultural, Automotive, Biomedical, Ceramic, Chemical, Civil, Communication, Computer, Electrical, Environmental, Food, Gas, Industrial & Production, Industrial, Marine, Mechanical, Mechatronics, Metallurgical & Material, Mining, Petrochemical, Petroleum, Production, Public Health, Refrigeration & Air-Conditioning, Structural, Systems, Textile & Polymer, Water Resources, Wood Products	Agricultural, Chemical, Civil, Electrical, Electronic, Communication, Mechanical, Metallurgical & Material, Water Resources & Environmental	Civil, Electrical & Electronic, Mechanical

Closed-Ended Survey

Closed-ended surveys were employed to gain insights into the perspectives of the Nigerian engineering community on sustainability issues as well as on curricular sustainability content. Consequently, three categories of survey were developed as follows: student survey, educator survey, and practitioner survey.

Student Survey

The student survey (see Appendix VI) contained 14 questions and was divided into demography and curricular assessment sections. Six demography-related questions were posed to obtain such information as name of respondent's HEI, engineering programme, gender, academic level, disposition towards sustainability in Nigeria, and awareness of UNDESD. The curricular assessment section featured an existing set of questions that had been developed by Watson (2013) premised on 37 STAUNCH® sustainability topics (Table 4.6). This cluster of questions sought the students' views on the extent to which these sustainability topics were covered in the Nigerian engineering curriculum as represented in their HEIs. The use of a 5-point Likert scale (*not at all - - to a great extent*) allowed the respondents to rate the coverage of the themes. The curricular assessment section also included a question on whether sustainability course or programme was offered in the HEI. Another inquiry probed students' opinions on ways they had learned about sustainability as well as on the means of effective sustainability intervention in the Nigerian engineering curriculum.

Educator Survey

The educator survey (see Appendix VII) contained 16 questions with the instrument divided into demography and curricular assessment sections. The six demography-related questions featured items such as name of university, engineering department, discipline, gender, academic qualification, disposition towards sustainability education in Nigeria, and awareness of UNDESD. The curricular assessment section featured the same set of questions as the curricular segment of the student survey adopted from Watson's (2013) instrument of 37 STAUNCH® sustainability topics (Table 4.6). The questions were, however, slightly modified to seek the educators' views on the extent to which they addressed these sustainability themes in their teaching of engineering. This was considered somewhat pertinent to the Nigerian engineering curriculum. Accordingly, the 5-point Likert scale (*not at all - - to a great extent*) on the survey allowed the educators to rate the spread of the sustainability topics. A question on whether a sustainability course or programme was offered in a respondent's university prefaced the curricular assessment section. Also, educators were queried on ways they had taught or encouraged the learning of sustainability in their HEIs as well as on the means of effective sustainability education intervention in Nigeria.

Practitioner Survey

The practitioner survey (see Appendix VIII) featured nine questions and was divided into the two sections of demography and miscellaneous information. Demography-eliciting questions inquired about respondents' engineering discipline, academic qualification, employment type, gender, years of professional experience, and awareness of UNDESD. The miscellaneous section contained a question on whether practitioners considered sustainability in engineering practice. Furthermore, there was a question that sought to establish the disposition of the practitioners towards sustainability in Nigeria. Lastly, a question on the practitioner survey explored respondents' views on the most appropriate sustainability education intervention for the Nigerian engineering curriculum. The 5-point Likert scale (*not at all - - extremely*) aided the rating of the responses. Practitioners were not asked questions relating to curricular sustainability content as the subgroup of the Nigerian engineering community were considered not sufficiently conversant with extant engineering curriculum in Nigeria.

Open-Ended Survey

Open-ended questions were interspersed with closed-ended questions on all the survey categories. The open-ended question common to all the surveys invited respondents to comment on sustainability and engineering education in Nigeria. This question came at the end of the surveys. One open-ended question posed to both educators and students requested them to think about all the engineering courses (taught or learned) in the HEIs and list three which addressed sustainability. The open-ended question uniquely posed to the practitioners asked them to state reasons for recognising (or not recognising) sustainability in engineering works. The open-ended questioning approach allowed respondents to express their thoughts without any restrictions. In phrasing the open-ended questions, careful thought was given to the need for brevity, clarity, and relevance. Additionally, the open-ended questions were made to feature in a way that reinforces logical flow of the entire survey. Overall, there were about four open-ended questions within the three survey categories.

Table 4.6. STAUNCH® sustainability topics[31]

Economic topics	Social topics
i. Gross National Product ii. Resource use iii. Finances iv. Production v. Developmental economics vi. Accountability	i. Demography & population ii. Employment & unemployment iii. Poverty iv. Bribery & corruption v. Equity & justice vi. Health vii. Politics viii. Education & training ix. Diversity & social cohesion x. Culture & religion xi. Labour & human rights xii. Peace & security
Environmental topics	**Crosscutting topics**
i. Environmental policy & law ii. Lifecycle assessment iii. Pollution iv. Biodiversity v. Resource efficiency vi. Climate change vii. Resource use: depletion viii. Land use: desertification ix. Alternative energy	i. People as part of nature ii. Systems thinking iii. Responsibility iv. Governance v. Holistic thinking vi. Long-term thinking vii. Communication & reporting viii. Sustainable development ix. Ethics & philosophy x. Transparency

Survey Pretesting

The student survey was piloted to 10 final-year engineering students at UCL and 10 postgraduate students in a Nigerian HEI. The educator survey was pretested by five Nigerian engineering educators. However, the practitioner survey was not piloted, but this inadequacy was mitigated by the insights gained from pretesting the student and educator surveys. Most of the issues raised in the trials were relevant to the three survey categories. An important observation from the trial of the surveys was that some of the questions were complex and needed to be simplified. Furthermore, the issue of ambiguity of concepts such as sustainability, socialism, and consumerism was raised. The survey pretesting also revealed the need to clarify instructions with respect

[31] Definitions of themes as employed in the current research are at Appendix IX.

to how respondents would answer the questions. These observations were considered in refining the surveys including the SLT. Of the original 20 SLT questions, only six were retained with nine fresh questions framed as a result of the survey trial.

Survey Administration

Paper-based and web-based means of survey administration were used in the present research. The paper-based survey involved physical distribution of the instrument to the respondents. The online survey, which was developed with the aid of web-based tool, *Opinio*, was accessed via a survey link. The survey length for both survey types was 15 minutes. Each survey was prefaced with a brief overview highlighting the purpose of the study and issues of confidentiality and voluntariness of participation. However, before the administration of the surveys, the three organisations involved in the study, namely COREN, HEI-1 and HEI-2 were formally invited to participate in the research (see Appendix X). An administrator was subsequently appointed by the organisations to coordinate the distribution of the surveys. Both the web-based and the paper-based surveys were routed through the representative of the organisations. The survey was administered (distributed and retrieved) over a period of three months (May – Aug 17). Follow up messages were sent fortnightly by the representatives to the respondents reminding and encouraging them to participate in the survey.

Workshop

Workshop was another data collection strategy employed in the current study. The event, which was entitled *Sustainable Engineering Workshop*, aimed to pilot an introductory sustainability course to undergraduate and postgraduate engineering students in Nigeria. Participants in the workshop were recruited randomly from Nigerian HEIs within Kaduna metropolis. In all 21 students partook in the workshop. Highlights of the workshop included preliminary assessments, lecture/presentation on sustainable engineering, sustainable engineering activity, and post-workshop tests. Whilst preliminary assessment involved a pre-workshop sustainability test, the post-workshop test featured a sustainability test as well as a workshop evaluation survey. Details of the workshop are provided in *Chapter Eight.*

Data Analysis

The analysis of data proceeded with the aid of computer software tools such as IBM SPSS (Version 22)[32] and NVivo11 Pro (Version 11.4)[33]. Details of the software packages are available on the websites of the products shown in the footnotes. The data analysis involved statistical analysis, SLT scoring and content analysis.

Statistical Analysis

Level of measurement typically informs the choice of statistical analysis and statistical tests. The level of measurement of a data refers to the meanings of the coding scheme or numbers associated with each variable (McCormick *et al*., 2015). Also known as scale of measurement, it is a description of the type or amount of information a variable or measure contains. Four levels of measurement have been identified in scientific research including nominal, ordinal, interval and ratio (Weisburd and Britt, 2014). Whilst nominal scale of measurement comprises categorical data without any precise order to the categories, ordinal data are characteristically ordered categories. The interval level of measurement features variables which are not only classified and ordered, but also maintain equal differences for all categories on the scale. Ratio data differs from interval data with the addition of a non-arbitrary or true zero value, with zero suggesting an absence of the trait being studied. The four levels of measurement are typically represented in a hierarchical relationship with nominal at the lowest level and ratio at the highest rung. Between the nominal and ratio scales are ordinal and interval levels respectively. Each higher level has the qualities of the level below it.

In the current research, nominal and ordinal levels of measurement constituted most of the data. Consequently, both descriptive and inferential statistics were undertaken in the study. Descriptive statistics uses measures of central tendency and measures of variability to summarise a given data set. The focus is on the summary of the basic features of the data or measure without necessarily reaching any conclusions about the sampled data. By contrast, inferential statistics seeks to deduce meaning from the sampled data and extend such inferences to more general conditions. As part of the data analysis in the present study, descriptive statistics were obtained using such measures of central tendency as mean and frequency as well as percentages. The

[32] https://www.ibm.com/products/spss-statistics
[33] https://www.qsrinternational.com

mean was calculated for all the categorical variables in the study, whilst the frequency of individual values was determined and presented on a frequency distribution table. The corresponding percentages for all the categories were equally calculated. The descriptive statistics provided a summary of the data with results presented graphically on a bar chart.

Inferential statistics in the study involved cross-tabulation, Pearson's chi-square test and repeated measures t-test. Cross-tabulation was used to explore the relationship between two or more categorical variables in the research with aid of percentages. The percentages of categorical variables were mapped against each other to identify patterns or relationship. Pearson's chi-square test was applied to detect any significant differences amongst the categorical variables in the data sets. A cut-off value[34] of 0.001 or lower ($p \leq 0.001$) was used for the chi-square test with the null hypothesis that the variables were unrelated to each other. The assumptions for conducting a Pearson's chi-square test, namely independence and large sample size, were met for the data in the present study. The repeated measures t-test was employed to check statistical differences in the pre- and post-workshop test performances of workshop participants. Using a cut-off value of 0.001 ($p < 0.001$) and a null hypothesis of no difference between mean pre- and post-marks, the t-test compared the differences to zero. To be valid, the t-test assumes normal distribution, and normality test ($p < 0.05$) conducted with the aid of QQ plot confirmed the data to be normally distributed. Hence, assumptions for inferential statistics were met for the data in the current study.

Sustainability Knowledge Assessment

The three criteria used to assess the sustainability knowledge of the sampled Nigerian engineering community were level of awareness of UNDESD, performance on SLT, and self-assessment of sustainability knowledge. The level of awareness of UNDESD was analysed statistically as already explained above. It was essentially a closed-ended question demanding a *yes* or *no* response to whether participants were aware of the UNDESD. The frequency and percentage of each response classification were obtained. SLT was graded based on a binary scoring format of *correct* or *incorrect* answers. Consequently, the fifteen test questions were each scored as either correct or incorrect. The percentage of respondents who opted for each answer category was

[34] The threshold p-values were chosen arbitrarily from $p < 0.05$, 0.01 and 0.001 options.

determined and the overall averages calculated. Although the SLT featured three options, namely *true*, *false*, and *do not know*, the *do not know* option was considered an incorrect response to suit the binary scoring format, but also because it represented a lack of knowledge about the queried item.

Respondents to the SLT were also assessed based on the four domains of economic, environmental, social and crosscutting sustainability. This was intended to determine the performance of the community by sustainability topics. The average scores of the respondents on each of the four sustainability domains were calculated and expressed as percentages. This aided a comparison of performances on the sustainability topics. For the self-assessment of sustainability knowledge, statistical analysis as explained previously was undertaken. However, the 5-point Likert scale of the self-assessment question (*very poor, poor, average, good, very good*) was reduced to low (*very poor – average*) and high (*good – very good*). This facilitated the delineation of self-assessed sustainability knowledge as either *low* or *high*, which did not only simplify the analysis but also provided a basis for comparison. Results of the three assessment criteria were synthesised to articulate the level of sustainability knowledge of the Nigerian engineering community.

Content Analysis

Content analysis in the present study involved three engineering documents, namely BMAS document, HEI-1 engineering handbook, and HEI-2 engineering handbook. The question that informed the content analysis of the engineering documents was whether or not sustainability topics were covered in the handbooks. It was therefore of interest to analyse the mentions of a sustainability topic or idea in any engineering programme contained in the documents. The documentary analysis involved the use of NVivo 11 Pro software. The engineering documents were converted to an editable PDF form, uploaded into the NVivo 11 Pro software and filed appropriately. Each engineering document was treated as a separate project on the software homepage. Thirty engineering programmes described in the BMAS document with the common engineering courses formed a total of 31 cases. The nine engineering programmes detailed in the HEI-1 engineering handbook and common engineering courses yielded a total of 10 cases, whilst the three courses of HEI-2 engineering document with the common courses produced a total of 4 cases.

A priori codes based on the four categories of environmental, economic, social, and crosscutting themes became parent nodes. In line with the STAUNCH® sustainability themes (Table 4.6), the environment node had 9 child nodes each being an important environment topic. Similarly, economic topics gave rise to 6 child nodes under the economic parent node, while the social parent node had 12 child nodes derived from myriad social issues like poverty, bribery, corruption, equity, etc. The crosscutting node contained 10 child nodes based on a range of multidimensional themes such as systems thinking, responsibility, holistic thinking, etc. The engineering documents were then scrutinised and coded at the cases and nodes. Words such as 'sustainable' used in the literal sense were not coded. Topics had to clearly embody sustainability ideas before being coded. Descriptive statistics for each engineering document were obtained and tabulated based on the model of Table 4.7.

Table 4.7. Model for descriptive statistics of engineering documents

Sustainability Theme	Frequency	Expected Occurrence	% within Potential Theme Content	NVivo % within Document
Subtopic 1	x	x	x	x
Subtopic 2	x	x	x	x
Subtopic 3	x	x	x	x
Theme content (Total)	x	x	x	x

The entries for the above table were obtained from NVivo11 Pro. NVivo 11 is a data analysis software tool designed to support qualitative data analyses. The computer software tool comprises several features that facilitate the management of complex, ill-defined and unstructured data. It is easy to organise, analyse and draw insights from an assorted dataset using the NVivo 11 Pro. The software supports a variety of data sources including emails, videos, online surveys, web-based interviews, photos, and social media platforms. NVivo 11 Pro aids researchers in source, theme, case, in-vivo and relationship coding which are invaluable to a mixed research data analysis. In the model table above, the sustainability theme column variously featured the four categories of economic, environmental, social and crosscutting topics and their subtopics, whilst the frequency column was used to enter the number of mentions of a subtopic obtained from the NVivo 11 as references coded. The process of obtaining frequencies of themes from textual data is sometimes referred to as quantitising

Expected occurrence column contained an anticipated mention of sustainability theme in the engineering documents, expressed as a function of the number of engineering programmes detailed in the documents including the common courses. The assumption was that each element of sustainability should be mentioned, at the least, once in each engineering programme. Thus, the expected occurrence of sustainability themes in the BMAS document, HEI-1 engineering handbook and HEI-2 engineering handbook was 31, 10 and 4 respectively (see Table 4.5). Percentage within potential theme content was calculated thus: (*Frequency/Expected Occurrence*) *X 100*. This equation provided an idea of how a sustainability theme, based on its spread potential, fared in terms of coverage within an engineering document.

The last column on the model table featured the percentage within an engineering document obtained directly from NVivo calculations. The NVivo percentage coverage for PDF documents is conventionally the average of the percentage of characters coded and the percentage of the page area coded. The outcome of this average is expressed as a percentage of the total document. The percentage of an engineering document covering a sustainability theme was calculated for all the documents and sustainability themes. The theme content row was used to calculate the sum of the entries in all the columns, which resulted in an overall assessment of the theme's content in the relevant document. Additionally, the location of a sustainability theme in an engineering document, i.e. the engineering programme in which a mention(s) of sustainability occurred was traced and presented on a stacked bar chart.

Open-Ended Survey Analysis

The qualitative data analysed in the study was generated by the questions on the list of sustainability courses in HEIs and general comments. For the sustainability courses, each mentioned course was coded as a node. Repeated mention of a course attracted coding at the same node, which eventually yielded a frequency table. The courses were subsequently arranged in an ascending order from the least to the most frequent. With regard to the general comments, an inductive coding approach was adopted. Themes were generated a posteriori from the data as opposed to a priori coding, resulting into distinct thematic categories. A matrix table was employed to present these emergent themes alongside their descriptions and illustrations from the data.

Validity and Reliability

An important goal of a mixed research is to draw inferences from the combined strengths of quantitative and qualitative research. Central to the issues of validity and reliability in a mixed research is the development of justified inferences (Onwuegbuzie and Johnson, 2006). However, justifying mixed research inferences, also called meta-inference, can be problematic for reasons of additive or multiplicative threats from the inherent shortcomings of both quantitative and qualitative research. The two elements of the mixed research could add or multiply the problems of validity and reliability manifest as the problem of integration. How successful (or otherwise) the integration of both the quantitative and qualitative strategies is affects the meta-inference quality of a mixed research. Threats to validity in the concurrent embedded mixed strategy of the present study largely involved such legitimation issues as sample integration, inside-outside legitimation, and weakness minimisation.

Sample integration describes "the extent to which the relationship between the quantitative and qualitative sampling yields quality meta-inferences" (Onwuegbuzie and Johnson, 2006). A common threat associated with sample integration is that unequal sample sizes may constrain the development of meta-inferences. In most cases the quantitative component constitutes a larger sample size than the qualitative element. Drawing a meta-inference from such arrangement can be severely limited especially if the qualitative sampling is unrepresentative of the target population. For example, it would be difficult from such setting to make statistical generalisations or inform population transferability. Random sampling and similarity of samples have been suggested as mitigation measures of sample integration issues (Ihantola and Kihn, 2011). An indicator of meta-inference quality is the degree of consistency between quantitative and qualitative inferences. In the present study, these factors played out in which the qualitative sample was randomly chosen and somewhat similar to the quantitative random sample, but also inferences therefrom were congruent.

Inside-outside legitimation underscores the accuracy of appropriately presenting both insider and outsider views for description and explanation purposes. This legitimation issue is sometimes difficult to attain as a result of researcher subjectivity. Peer review has been recommended as an extenuating measure (Creswell, 2014). In the current research, peer review was augmented by bias clarification or reflexivity to critique descriptions, explanations and interpretations. At least one representative each from the three groups of the Nigerian engineering community namely, students, educators, and practitioners partook in reviewing the interpretations of the research. Relevant portions of the findings were messaged to these individuals via the organisations' contacts. This included aspects of both the quantitative and qualitative components of the research. The combined interpretation of the study was reviewed by a duo of disinterested social research academics. With regard to reflexivity, a germane issue was the researcher's "*enduring urge to bring about a positive change in an educational system through which I passed*" (see *Preface*). It was thus important to ensure that this desire did not compromise the findings of the study. Consequently, interpretations in the present study were repeatedly checked against such potential bias.

Weakness minimisation describes the degree of reducing the inherent flaws of one approach by the other. This is simply one of the objectives of mixed research strategy. However, the extent to which the quantitative and qualitative approaches complement each other is not readily determinable. Onwuegbuzie and Johnson (2006) advise that researchers should conscientiosuly evaluate the compensatory effects of quantitatve and qualitative components of an adopted mixed research strategy. This is obviously not an uncomplicated process as some weaknesses are only noticeable during the fieldwork. Nonetheless, threats to validity of the mixed research components were identified and appropriately addressed in the current study. The limitation sections of the findings chapters were devoted to highlighting the validity issues pertinent to the chapters. In terms of reliability, iterative checks for mistakes during instrumentation, coding, decoding and other data collection and analysis procedures were rigorously undertaken. Additionally, survey pretesting as already discussed proved useful in ensuring the reliability of the surveys.

Ethical Issues

Ethical issues considered in this study cut across the various research stages of planning, data collection and data analysis. Prior to commencing the fieldwork, ethical advice from UCL Research Ethics Committee determined that an ethical approval was not required. The study was identified under the exemption category as it involved "*the use of non-sensitive, completely anonymous educational tests, survey and interview procedures [and] the participants are not defined as "vulnerable" and participation will* *not induce undue psychological stress or anxiety.*"[35] Nonetheless, conventional ethical standards were observed throughout the research. An ethical concern prior to the fieldwork was access to the Nigerian engineering community. To address this issue, a formal request for access to engineering practitioners, educators and students was sought and obtained from appropriate authorities. Only after access approval had been secured did the study proceed. In the course of the fieldwork, ethical issues arose from interaction with participants bordering on confidentiality and voluntariness of participation. These concerns were adequately addressed on the consent forms issued to the respondents which clearly stated the purpose of the study.

To ensure confidentiality, data were anonymised throughout the study. The HEIs that were involved in the study, the survey respondents and the workshop participants were given codes to hide their identities. For example, the two education institutions in the study were referred to as HEI-1 and HEI-2 and their documents dubbed HEI-1 and HEI-2 engineering handbooks respectively. Practitioners were anonymised as PR, educators as ER, and students as SR. An integer was randomly assigned to these letters to create a code of sorts such as PR1, ER10 and SR235 corresponding to first practitioner respondent, tenth educator respondent, and two hundred and thirty-fifth student respondent. Additional ethical concerns considered during the analysis of data included issues of reporting findings and data sharing. Concerted efforts were made to eschew data falsification, plagiarism, dishonesty, disregard of discrepant data, and unethical sharing of findings.

Challenges

There is no research methodology that can be devoid of drawbacks. Some of the challenges encountered in the present study included missing data, apathy toward internet-based survey, and disinclination to participate in a sustainability research. As regards missing data, only 20 cases out of 442 responses were reported throughout the study. Interestingly, 17 of these missing data affected one survey item, whilst the remaining three cases affected another survey element. Given the comparatively low impact of the missing data, they were omitted in the data analysis. Another challenge the study faced was apathy toward internet-based survey. This obstacle was chiefly

[35] https://ethics.grad.ucl.ac.uk/exemptions.php

encountered in organisations whose management declined to publish the survey link of the research on their official websites. For some unclear reasons, the authorities of these institutions approved the use of only paper-based surveys.

In organisations where the survey link was published online the responses were surprisingly poor. A possible explanation could be the poor availability of internet access in most Nigerian HEIs. This deprived the research of such online survey merits as convenience and expeditious data analysis (especially from the compatibility of *Opinio* with IBM SPSS and NVivo 11 Pro). Lastly, some members of the Nigerian engineering community were disinclined to partake in the study for religious reasons. The crux of their argument was that the idea of sustainability conflicted directly with the divine attributes of sustenance and providence. This position might not have been pervasive given the sample size achieved in the research. However, its possible espousal by academics begs the question of how many people refrained from participating in the study based on such convictions.

Summary

The central query of the current research posed the question of what sustainability education interventions are appropriate for the Nigerian engineering curriculum. To address this key question, the study required data about the level of sustainability knowledge of the engineering community and the sustainability content of the Nigerian engineering curriculum. Mixed research underlain by the pragmatist philosophy was adopted in the study. This chapter reviewed the methodology of the research stressing the import of sustainability assessment vis-à-vis sustainability content and literacy. The choice of the *concurrent embedded mixed research strategy* in the conduct of the study was rationalised. The chapter further detailed the research design employed in the study covering a range of topics including survey population, sample size, data collection and data analysis methods. Data collection methods discussed in the chapter included sustainability literacy test, content analysis, closed-ended and open-ended surveys as well as workshop. The data analysis method involved the use of IBM SPSS and NVivo11 Pro computer software tools to facilitate statistical analysis, sustainability knowledge assessment and content analysis. The chapter ended with an overview of validity, reliability, ethical issues and challenges of the research. *Chapter Five* presents the findings of the first research question.

Chapter Five

5 Sustainability Literacy of Nigerian Engineering Community

Introduction

This chapter assesses the sustainability literacy level of the Nigerian engineering community. It responds to the question: *What is the current level of sustainability knowledge of the Nigerian engineering community?* Answers to the question were derived from a survey administered to three groups within the engineering community, namely students (n=232), educators (n=84) and practitioners (n=126). Three criteria against which the sustainability literacy of the community was measured included level of UNDESD awareness, performance on a sustainability literacy test, and self-assessment of sustainability knowledge. The chapter proceeds by describing the results of the assessment of students followed by those of educators and practitioners. The results are synthesised to approximate the sustainability literacy of the entire engineering community (n=442). The chapter concludes with a discussion of the results and limitations of the study.

Student Literacy

Awareness of UN Decade of Education for Sustainable Development

Inquiry into students' awareness of the UN Decade of Education for Sustainable Development (UNDESD) revealed that a vast majority (81%) of the students were not aware of the Decade (Table 5.1). Disaggregating the data by institution, discipline and educational level revealed no statistically significant differences ($p \leq 0.001$). Thus, engineering students were generally unaware of the UNDESD.

Table 5.1. Students' awareness of UNDESD

***Survey prompt**: Are you aware of the UN Decade of Education for Sustainable Development?*		(n =232) **Frequency**	P ≤ 0.001 **Percent**
	Yes	44	19.0
	No	188	81.0
	Total	232	100.0

Outcome of Sustainability Literacy Test

Overall Performance

Table 5.2 shows the performance of the sampled student population (n = 232) in the sustainability literacy test, which is expressed as a percentage of students responding correctly or incorrectly to 15 sustainability-related questions. There is also an option for the 'do not know' response. The correct answers are parenthesised in italics and placed next to each question. Only Q8 was correctly answered by more than half (51.7%) of the students. The average percentage of students who answered the questions incorrectly was 32.1%, whilst almost half of the students (48.8%) admitted not knowing the answers. There were no significant differences based on institution, discipline and educational level ($p \leq 0.001$). Thus, a significant number of the students did not answer the sustainability test questions correctly.

Table 5.2. Student performance on sustainability literacy test

Sustainability Literacy Test - Students	n = 232		
	% within group		
Question	**Correct**	**Incorrect**	**Do not know**
Q1. Ozone layer protects us from acid rain and temperature fluctuations. (*False*)	10.0	66.1	23.9
Q2. Carbon monoxide is one of the greenhouse gases that cause global warming. (*False*)	7.8	67.0	25.2
Q3. The main focus of the Kyoto Protocol adopted in 1997 was nuclear waste. (*False*)	7.4	16.1	76.5
Q4. Agenda 21 is a global treaty signed by UN member nations at the Stockholm Earth Summit in 1992. (*False*)	6.1	20.9	73.0
Q5. Global population stood at 1.6 billion in 1900. (*True*)	28.3	7.8	63.9
Q6. Less than one million people in the world have no access to clean drinking water. (*False*)	28.3	26.5	45.2
Q7. Engineers' role in sustainability suffices with ensuring that their designs or systems do not harm the environment. (*False*)	10.5	63.8	25.8
Q8. Long-term profitability is the most commonly used definition of economic sustainability. (*True*)	51.7	13.5	34.8
Q9. The review of global poverty line to US $ 1.90 was spurred by worldwide sustainability activisms. (*False*)	5.2	19.6	75.2
Q10. Economic development and environmental protection are mutually exclusive. (*False*)	27.4	36.5	36.1
Q11. The sustainability pillars of environment, society and economy are widely accepted to be in a hierarchical, rather than equal, relationship. (*False*)	14.8	39.3	45.9
Q12. In the landmark Brundtland Report of 1987, the terms *sustainability* and sustainable development are used interchangeably. (*True*)	22.6	6.1	71.3
Q13. Nigeria failed to ratify the UN 2030 Agenda for Sustainable Development in 2015 as presidential elections held in the country at the time. (*False*)	13.1	21.4	65.5
Q14. Federal Environmental Protection Agency is the primary agency that oversees environmental regulation in Nigeria. (*False*)	10.0	54.8	35.2
Q15. Breeding of animals in zoos is the most significant driver in the loss of species and ecosystems around the world. (*False*)	43.7	22.3	34.0
Average	**19.1**	**32.1**	**48.8**

Performance by Sustainability Topics

An assessment of the students' performance across sustainability themes revealed that economic topics had, on average, the highest percentage (35.8%) of correctly answered questions followed by the environmental themes (20.5%). Social and crosscutting topics recorded small fractions of correct responses – 14.7% and 9.4% respectively (Table 5.3). There were no statistically significant differences within the student population excepting slight variation based on educational level. Postgraduate students performed better than undergraduate students only on economic questions ($p \leq 0.001$). However, no significant differences were observed in the remaining sustainability topics. Hence, the sustainability literacy of the students by topics did not vary greatly based on educational level.

Table 5.3. Student performance across sustainability pillars

Sustainability Literacy Test - Students (n=232)							
	% within group				% within group		
Economic topics	**Correct**	**Incorrect**	**Do not know**	**Social topics**	**Correct**	**Incorrect**	**Do not know**
Q5. Global population stood at 1.6 billion in 1900. (*True*)	28.3	7.8	63.9	Q6. Less than one million people in the world have no access to clean drinking water. (*False*)	28.3	26.5	45.2
Q8. Long-term profitability is the most commonly used definition of economic sustainability. (*True*)	51.7	13.5	34.8	Q7. Engineers' role in sustainability suffices with ensuring that their designs or systems do not harm the environment. (*False*)	10.5	63.8	25.8
Q10. Economic development and environmental protection are mutually exclusive. (*False*)	27.4	36.5	36.1	Q9. The review of global poverty line to US $ 1.90 was spurred by worldwide sustainability criticisms. (*False*)	5.2	19.6	75.2
Average	**35.8**	**19.3**	**44.9**	**Average**	**14.7**	**36.6**	**48.7**
Environmental topics				**Crosscutting topics**			
Q1. Ozone layer protects us from acid rain and temperature fluctuations. (*False*)	10.0	66.1	23.9	Q3. The main focus of the Kyoto Protocol adopted in 1997 was nuclear waste. (*False*)	7.4	16.1	76.5
Q2. Carbon monoxide is one of the greenhouse gases that cause global warming. (*False*)	7.8	67.0	25.2	Q4. Agenda 21 is a global treaty signed by UN member nations at the Stockholm Earth Summit in 1992. (*False*)	6.1	20.9	73.0
Q15. Breeding of animals in zoos is the most significant driver in the loss of species and ecosystems around the world. (*False*)	43.7	22.3	34.0	Q11. The sustainability pillars of environment, society and economy are widely accepted to be in a hierarchical, rather than equal, relationship. (*False*)	14.8	39.3	45.9
Average	**20.5**	**51.8**	**27.7**	**Average**	**9.4**	**25.4**	**65.1**

Student Self-Assessment of Sustainability Knowledge

Students assessed their performance on the sustainability literacy test (Table 5.4 and Figure 5.1). Most students (79%) rated their sustainability knowledge between *very poor* and *average*. Only a fraction of the students (21%) considered their sustainability literacy as either *good* or *very good*. No significant differences were found based on institution, discipline and academic level ($p \leq 0.001$).

Table 5.4. Student self-assessment of sustainability literacy

Survey prompt*: Based on your response to SLT questions, how would you rate your sustainability knowledge?*		(n = 230) **Frequency**	P ≤ 0.001 **Percent**
	Very poor	9	3.9
	Poor	54	23.5
	Average	118	51.3
	Good	44	19.1
	Very good	5	2.2
	Total	230	100.0

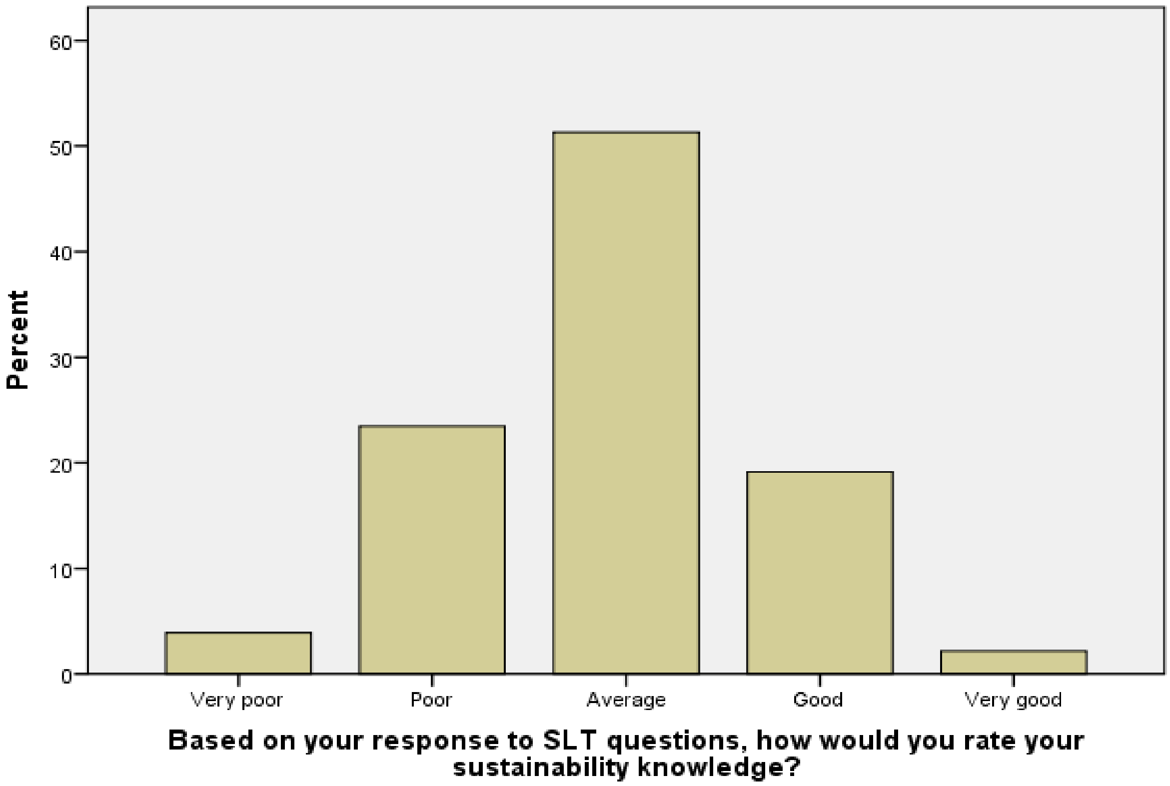


Figure 5.1. Students' sustainability literacy perception

Educator Literacy

Awareness of UN Decade of Education for Sustainable Development

Awareness of the UNDESD amongst educators was somewhat poor as most of them (66.7%) were uninformed about the declaration (Table 5.5). Only one-third of the educators (33.3%) said they knew about the UN Decade. Additionally, UNDESD awareness did not differ significantly across institution (p = 0.746), discipline (p = 0.298) and academic qualification (p = 0.719). Thus, engineering educators generally had inadequate knowledge of the UN Decade of ESD.

Table 5.5. Educators' awareness of UNDESD

Survey prompt*: Are you aware of the UN Decade of Education for Sustainable Development?*		(n=84) **Frequency**	P ≤ 0.001 **Percent**
	Yes	28	33.3
	No	56	66.7
	Total	84	100.0

Outcome of Sustainability Literacy Test

Overall Performance

Results (Table 5.6) of the sustainability literacy test revealed that only one-fifth (20.9%) of the educators performed well on the test. One-third (33.1%) and almost half (46.0%) of the educators respectively answered the questions incorrectly and with a 'do not know' response. Nonetheless, a large proportion (61.4%) responded correctly to Q8. The most incorrectly answered question on the test was Q9 attracting only a small fraction of correct responses (3.6%). Disaggregating the data by institution, discipline and academic qualification did not reveal any statistically significant differences ($p \leq 0.001$). Hence, the performance of the engineering educators on the sustainability literacy test was mostly poor.

Table 5.6. Educator performance on sustainability literacy test

Sustainability Literacy Test - Educators	n = 84		
Question	% within group		
	Correct	Incorrect	Do not know
Q1. Ozone layer protects us from acid rain and temperature fluctuations. (*False*)	10.8	72.3	16.9
Q2. Carbon monoxide is one of the greenhouse gases that cause global warming. (*False*)	12.0	66.3	21.7
Q3. The main focus of the Kyoto Protocol adopted in 1997 was nuclear waste. (*False*)	13.3	21.7	65.1
Q4. Agenda 21 is a global treaty signed by UN member nations at the Stockholm Earth Summit in 1992. (*False*)	4.8	21.7	73.5
Q5. Global population stood at 1.6 billion in 1900. (*True*)	25.3	14.5	60.2
Q6. Less than one million people in the world have no access to clean drinking water. (*False*)	49.4	13.3	37.3
Q7. Engineers' role in sustainability suffices with ensuring that their designs or systems do not harm the environment. (*False*)	4.8	73.5	21.7
Q8. Long-term profitability is the most commonly used definition of economic sustainability. (*True*)	61.4	10.8	27.7
Q9. The review of global poverty line to US $ 1.90 was spurred by worldwide sustainability activisms. (*False*)	3.6	18.1	78.3
Q10. Economic development and environmental protection are mutually exclusive. (*False*)	31.3	39.8	28.9
Q11. The sustainability pillars of environment, society and economy are widely accepted to be in a hierarchical, rather than equal, relationship. (*False*)	7.2	43.4	49.4
Q12. In the landmark Brundtland Report of 1987, the terms *sustainability* and sustainable development are used interchangeably. (*True*)	21.7	1.2	77.1
Q13. Nigeria failed to ratify the UN 2030 Agenda for Sustainable Development in 2015 as presidential elections held in the country at the time. (*False*)	12.0	20.5	67.5
Q14. Federal Environmental Protection Agency is the primary agency that oversees environmental regulation in Nigeria. (*False*)	7.2	61.4	31.3
Q15. Breeding of animals in zoos is the most significant driver in the loss of species and ecosystems around the world. (*False*)	49.4	18.1	32.5
Average	**20.9**	**33.1**	**46.0**

Performance by Sustainability Topics

Educators had a varied performance by sustainability topics (Table 5.7). A good proportion (39.3%) of the educators performed well on the economic questions, but did poorly (8.4%) on the crosscutting topics. Less than a quarter of the educators (19.2%) answered the social questions correctly. The environmental questions trailed behind the social topics with nearly a quarter (24.1%) of the lecturers responding with correct answers. There were no statistically significant differences based on the educators' institution, discipline and academic qualification ($p \leq 0.001$). Thus, the educators' knowledge of sustainability differed by topics, but was largely the same across institutions and academic levels.

Table 5.7. Educator performance across sustainability topics

Sustainability Literacy Test - Educators (n=84)							
	% within group				% within group		
Economic topics	**Correct**	**Incorrect**	**Do not know**	**Social topics**	**Correct**	**Incorrect**	**Do not know**
Q5. Global population stood at 1.6 billion in 1900. (*True*)	25.3	14.5	60.2	Q6. Less than one million people in the world have no access to clean drinking water. (*False*)	49.4	13.3	37.3
Q8. Long-term profitability is the most commonly used definition of economic sustainability. (*True*)	61.4	10.8	27.7	Q7. Engineers' role in sustainability suffices with ensuring that their designs or systems do not harm the environment. (*False*)	4.8	73.5	21.7
Q10. Economic development and environmental protection are mutually exclusive. (*False*)	31.3	39.8	28.9	Q9. The review of global poverty line to US $ 1.90 was spurred by worldwide sustainability criticisms. (*False*)	3.6	18.1	78.3
Average	**39.3**	**21.7**	**38.9**	**Average**	**19.2**	**35.0**	**45.8**
Environmental topics				**Crosscutting topics**			
Q1. Ozone layer protects us from acid rain and temperature fluctuations. (*False*)	10.8	72.3	16.9	Q3. The main focus of the Kyoto Protocol adopted in 1997 was nuclear waste. (*False*)	13.3	21.7	65.1
Q2. Carbon monoxide is one of the greenhouse gases that cause global warming. (*False*)	12.0	66.3	21.7	Q4. Agenda 21 is a global treaty signed by UN member nations at the Stockholm Earth Summit in 1992. (*False*)	4.8	21.7	73.5
Q15. Breeding of animals in zoos is the most significant driver in the loss of species and ecosystems around the world. (*False*)	49.4	18.1	32.5	Q11. The sustainability pillars of environment, society and economy are widely accepted to be in a hierarchical, rather than equal, relationship. (*False*)	7.2	43.4	49.4
Average	**24.1**	**52.2**	**23.7**	**Average**	**8.4**	**28.9**	**62.7**

Educator Self-Assessment of Sustainability Knowledge

The sustainability self-assessment scores showed that most educators (61%) gauged their sustainability knowledge as *very poor*, *poor* or *average* (Table 5.8 and Figure 5.2). Interestingly, over a third (39%) of the educators assessed their sustainability literacy as either *good* or *very good*. There were no statistically significant differences based on institution, discipline and academic qualification ($p \leq 0.001$). Thus, a sizeable proportion of the educators considered themselves sufficiently knowledgeable about sustainability.

Table 5.8. Educator self-assessment of sustainability literacy

***Survey prompt**: Based on your response to SLT questions, how would you rate your sustainability knowledge?*		n = 83 **Frequency**	P ≤ 0.001 **Percent**
	Very poor	3	3.6
	Poor	20	24.1
	Average	28	33.7
	Good	25	30.1
	Very good	7	8.4
	Total	83	100.0

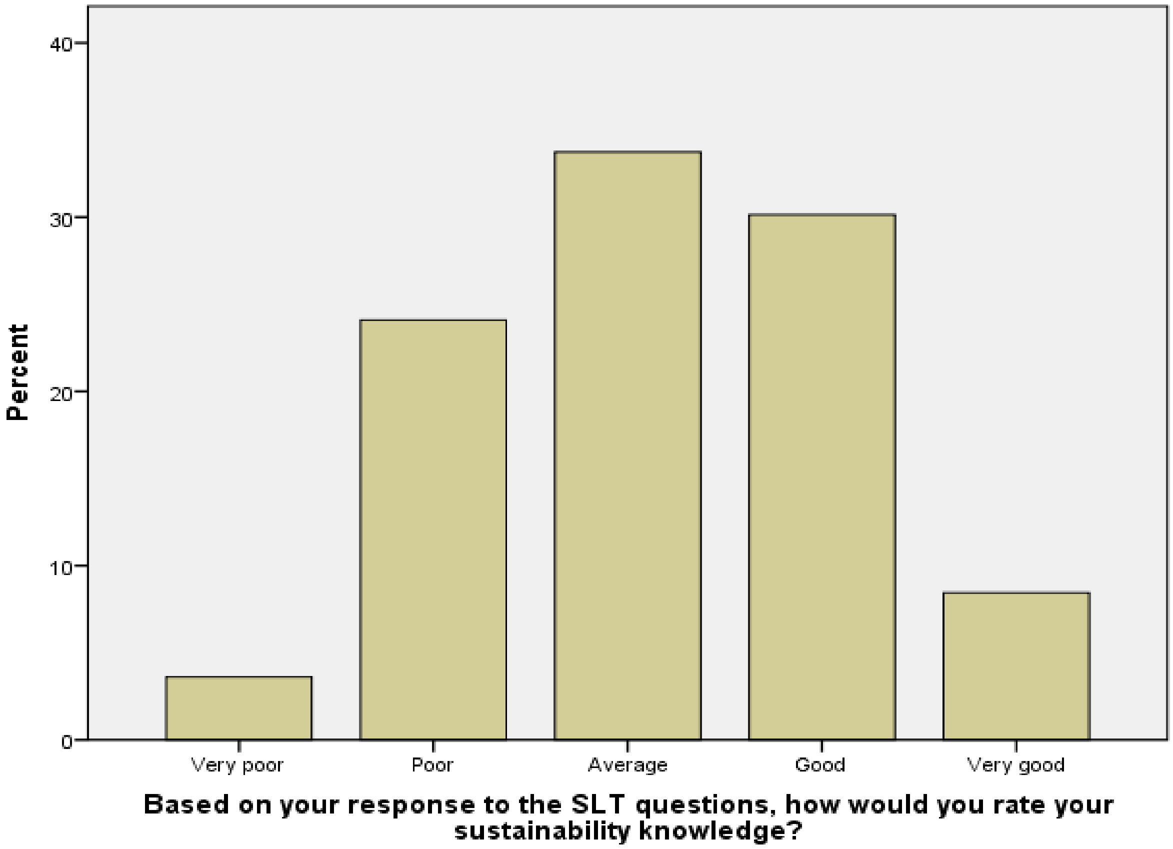


Figure 5.2. Educators' sustainability literacy perception

Practitioner Literacy

Awareness of UN Decade of Education for Sustainable Development

Practitioners differed on their awareness of the UNDESD (Table 5.9). Whilst a considerable number of the practitioners (35.7%) knew about the UN Decade, the majority (64.3%) was ignorant of it. Disaggregating the data by discipline, employment type, and length of professional experience revealed no statistically significant differences ($p \leq 0.001$). Hence, engineering practitioners were mostly unaware of the UNDESD.

Table 5.9. Practitioners' awareness of UNDESD

Survey prompt*: Are you aware of the UN Decade of Education for Sustainable Development?*		(n = 126) **Frequency**	**Percent**
	Yes	45	35.7
	No	81	64.3
	Total	126	100.0

Outcome of Sustainability Literacy Test

Overall Performance

The sustainability literacy test of the practitioners recorded a significant amount of incorrect responses (Table 5.10). Only one-quarter of the respondents answered the sustainability questions correctly. More than two-fifths (40.5%) of the practitioners responded incorrectly to the questions, whilst one-third of them indicated not knowing the correct answers. Interestingly, the majority of the practitioners answered Q6 and Q8 correctly having recorded 52.1% and 75.2% correct responses respectively. However, the practitioners did not differ significantly based on discipline, employment type, academic qualification and length of professional experience ($p \leq 0.001$). Hence, the overall performance of the practitioners on the sustainability literacy test was generally poor.

Table 5.10. Practitioner performance on sustainability literacy test

Sustainability Literacy Test - Practitioners	**n = 126**		
Question	**% within group**		
	Correct	**Incorrect**	**Do not know**
Q1. Ozone layer protects us from acid rain and temperature fluctuations. (*False*)	17.1	76.9	6.0
Q2. Carbon monoxide is one of the greenhouse gases that cause global warming. (*False*)	6.8	86.3	6.9
Q3. The main focus of the Kyoto Protocol adopted in 1997 was nuclear waste. (*False*)	11.1	17.1	71.8
Q4. Agenda 21 is a global treaty signed by UN member nations at the Stockholm Earth Summit in 1992. (*False*)	5.1	27.4	67.5
Q5. Global population stood at 1.6 billion in 1900. (*True*)	35.0	10.3	54.7
Q6. Less than one million people in the world have no access to clean drinking water. (*False*)	52.1	21.4	26.5
Q7. Engineers' role in sustainability suffices with ensuring that their designs or systems do not harm the environment. (*False*)	12.8	82.9	4.3
Q8. Long-term profitability is the most commonly used definition of economic sustainability. (*True*)	75.2	11.1	13.7
Q9. The review of global poverty line to US $ 1.90 was spurred by worldwide sustainability activisms. (*False*)	7.7	25.6	66.7
Q10. Economic development and environmental protection are mutually exclusive. (*False*)	38.5	46.2	15.3
Q11. The sustainability pillars of environment, society and economy are widely accepted to be in a hierarchical, rather than equal, relationship. (*False*)	10.3	57.2	32.5
Q12. In the landmark Brundtland Report of 1987, the terms *sustainability* and sustainable development are used interchangeably. (*True*)	25.9	6.0	68.1
Q13. Nigeria failed to ratify the UN 2030 Agenda for Sustainable Development in 2015 as presidential elections held in the country at the time. (*False*)	20.5	24.8	54.7
Q14. Federal Environmental Protection Agency is the primary agency that oversees environmental regulation in Nigeria. (*False*)	6.8	77.8	15.4
Q15. Breeding of animals in zoos is the most significant driver in the loss of species and ecosystems around the world. (*False*)	44.4	35.9	19.7
Average	**24.6**	**40.5**	**34.9**

Performance by Sustainability Topics

The performance of practitioners on the sustainability literacy test varied according to sustainability themes (Table 5.11). Nearly half of the practitioners (49.6%) performed well on the economic questions. Almost a quarter of them (24.2%) passed the social queries with a fraction of the professionals (22.8%) answering the environmental questions correctly. However, a considerable majority either performed poorly or did not know the correct answers to the crosscutting questions. Disaggregating the data by discipline, employment, academic qualification and length of professional experience revealed no statistically significant differences ($p \leq 0.001$). Therefore, practitioners' performance on the test, although differed across sustainability themes, neither depended on engineering specialty nor on practice circumstances.

Table 5.11. Practitioner performance across sustainability topics

Sustainability Literacy Test - Practitioners (n=126)							
	% within group				% within group		
Economic topics	**Correct**	**Incorrect**	**Do not know**	**Social topics**	**Correct**	**Incorrect**	**Do not know**
Q5. Global population stood at 1.6 billion in 1900. (*True*)	35.0	10.3	54.7	Q6. Less than one million people in the world have no access to clean drinking water. (*False*)	52.1	21.4	26.5
Q8. Long-term profitability is the most commonly used definition of economic sustainability. (*True*)	75.2	11.1	13.7	Q7. Engineers' role in sustainability suffices with ensuring that their designs or systems do not harm the environment. (*False*)	12.8	82.9	4.3
Q10. Economic development and environmental protection are mutually exclusive. (*False*)	38.5	46.2	15.3	Q9. The review of global poverty line to US $ 1.90 was spurred by worldwide sustainability criticisms. (*False*)	7.7	25.6	66.7
Average	**49.6**	**22.5**	**27.9**	**Average**	**24.2**	**43.3**	**32.5**
Environmental topics				**Crosscutting topics**			
Q1. Ozone layer protects us from acid rain and temperature fluctuations. (*False*)	17.1	76.9	6.0	Q3. The main focus of the Kyoto Protocol adopted in 1997 was nuclear waste. (*False*)	11.1	17.1	71.8
Q2. Carbon monoxide is one of the greenhouse gases that cause global warming. (*False*)	6.8	86.3	6.9	Q4. Agenda 21 is a global treaty signed by UN member nations at the Stockholm Earth Summit in 1992. (*False*)	5.1	27.4	67.5
Q15. Breeding of animals in zoos is the most significant driver in the loss of species and ecosystems around the world. (*False*)	44.4	35.9	19.7	Q11. The sustainability pillars of environment, society and economy are widely accepted to be in a hierarchical, rather than equal, relationship. (*False*)	10.3	57.2	32.5
Average	**22.8**	**66.4**	**10.8**	**Average**	**8.8**	**33.9**	**57.3**

Practitioner Self-Assessment of Sustainability Knowledge

Table 5.12 and Figure 5.3 show results of sustainability self-assessment undertaken by engineering practitioners. More than half (58.1%) of the practitioners assessed their sustainability knowledge as *average*. A fairly sizable proportion (30.8%) perceived themselves as having a *good* sustainability literacy with a negligible number (1.7%) rating their knowledge as *very good*. There were no statistically significant differences based on discipline, employment, academic qualification and length of experience ($p \leq 0.001$).

Table 5.12. Practitioner self-assessment of sustainability literacy

Survey prompt*: Based on your response to SLT questions, how would you rate your sustainability knowledge?*		(n = 117) **Frequency**	P ≤ 0.001 **Percent**
	Very poor	2	1.7
	Poor	9	7.7
	Average	68	58.1
	Good	36	30.8
	Very good	2	1.7
	Total	117	100.0

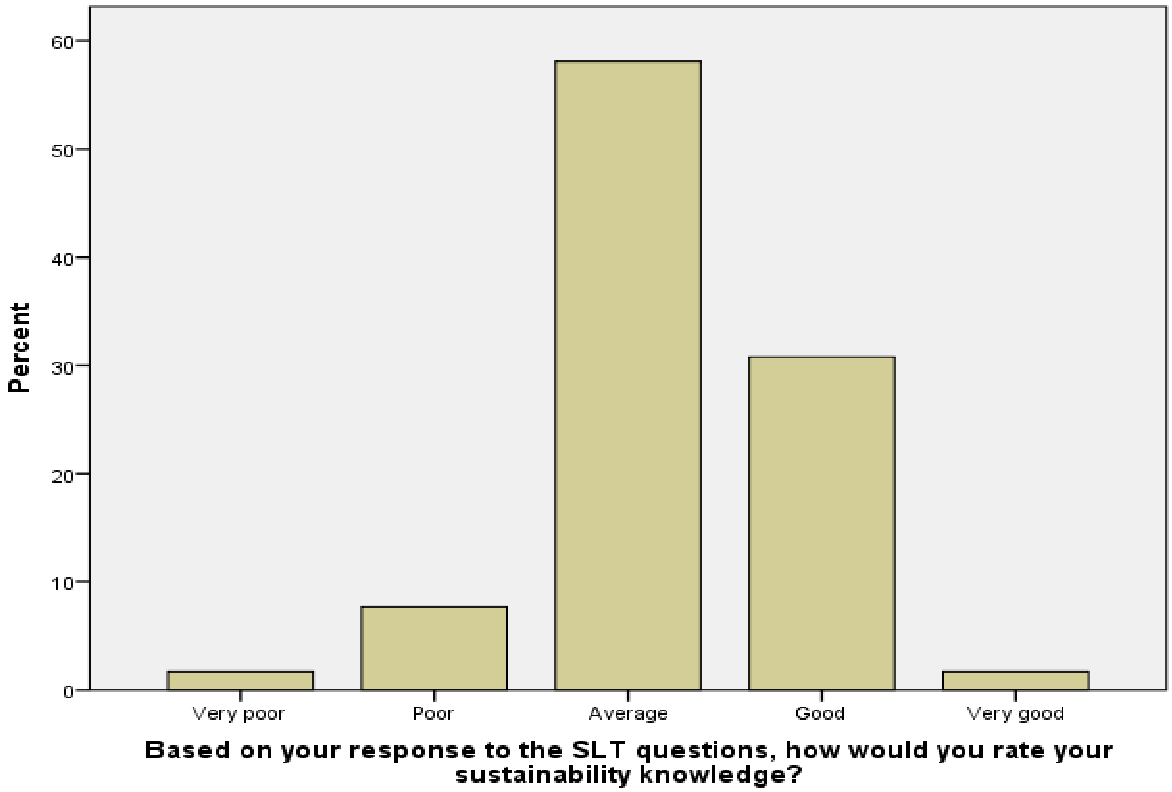


Figure 5.3. Practitioners' sustainability literacy perception

Result Synthesis

Combining results of the three groups within the Nigerian engineering community fostered a holistic insight into the sustainability literacy of the community (Table 5.13). For the level of UNDESD awareness, the results showed Nigerian engineering community as generally unaware of the UN Decade. On average, just over a quarter (29%) of the engineering community was cognisant of the Decade with a significant majority (71%) admitting ignorance. However, the difference in the level of awareness amongst the three categories was observed to be statistically significant ($p \leq 0.001$). Educators (33%) and practitioners (36%) indicated a higher level of UNDESD awareness than did students (19%). Hence, students seemed most uninformed about the Decade.

Table 5.13. Sustainability literacy of Nigerian engineering community

Engineering Community (n=442; $p \leq 0.001$)	% UNDESD Awareness		% SLT Score			% SK Self-Assessment	
	Yes	**No**	**Correct**	**Incorrect**	**Do not know**	**High***	**Low****
Students (n=232)	19	81	19	32	49	21	79
Educators (n=84)	33	67	21	33	46	39	61
Practitioners (n=126)	36	64	25	40	35	33	67
Average	**29**	**71**	**22**	**35**	**43**	**31**	**69**

** High = very good or good ** Low = very poor – average*

The overall performance of the Nigerian engineering community on the sustainability literacy test was poor. Scores revealed a nearly eighty percent incorrect and 'do not know' responses with just over a fifth (22%) of the community answering the questions correctly. No significant differences were observed in the performance across the cohorts, although practitioners performed slightly better than the educators and students, respectively. Sustainability test performance by topics (Table 5.14) revealed statistically significant differences within the engineering community ($p \leq 0.001$). Generally, the community demonstrated strength in economic themes with over two-fifths of them (42%) answering the relevant questions correctly. The least known topics were the crosscutting issues whose questions were answered correctly by only a small minority of the community (9%). Performance of the engineering community on the social and environmental themes was quite low having recorded some significant amount of wrong answers (38% and 57% respectively). Nonetheless, across the three groups, practitioners excelled in economic and social issues, whilst educators performed best on environmental topics. Students performed better than educators on the crosscutting sustainability themes.

Table 5.14. Performance of stakeholders by sustainability topics

Engineering Community (n=442; *p* ≤ 0.001)	Economic			Social			Environmental			Crosscutting		
	Correct %	Incorrect %	Do not Know %	Correct %	Incorrect %	Do not Know %	Correct %	Incorrect %	Do not Know %	Correct %	Incorrect %	Do not Know %
Students (n = 232)	35.8	19.3	44.9	14.7	36.6	48.7	20.5	51.8	27.7	9.4	25.4	65.1
Educators (n = 84)	39.3	21.7	38.9	19.2	35.0	45.8	24.1	52.2	23.7	8.4	28.9	62.7
Practitioners (n = 126)	49.6	22.5	27.9	24.2	43.3	32.5	22.8	66.4	10.8	8.8	33.9	57.3
Average	**41.6**	**21.2**	**37.2**	**19.4**	**38.3**	**42.3**	**22.5**	**56.8**	**20.7**	**8.9**	**29.4**	**61.7**

Results of the sustainability knowledge self-assessment revealed that the Nigerian engineering community mostly rated their sustainability knowledge low. Only 3 in 10 people (31%) had a high opinion of their sustainability knowledge. Comparing the outcome of the self-assessment of sustainability knowledge with actual performance on the test was quite revealing (Table 5.15). Perception of sustainability knowledge differed markedly from actual scores. For instance, some 21% of the students thought themselves as possessing either *good* or *very good* sustainability knowledge, but only 5% of them passed the test. Similarly, of the over one-third (39%) of the educators who claimed to have either *good* or *very good* sustainability literacy, only a fraction (10%) passed the test. Equally, only a small minority (9%) of the one-third practitioners (33%) with high estimation (*good* or *very good*) of their sustainability knowledge performed well on the test. On the whole, even though a proportion of the engineering community (31%), on average, rated their sustainability knowledge high, quite an insignificant number of them (8%) passed the test. However, it is noteworthy that fewer students admitted having adequate sustainability knowledge compared with educators and practitioners.

Table 5.15. Comparing self-assessment with actual test scores

Engineering Community (n=442; *p* ≤ 0.001)	**Self-Assessment**	**SLT Score**
	% of *good* or *very good* claim	% of actual pass on test
Students	21	5
Educators	39	10
Practitioners	33	9
Average	**31**	**8**

Discussion

The three criteria used to gauge the sustainability literacy of the Nigerian engineering community are level of UNDESD awareness, score on sustainability literacy test, and self-assessment of sustainability knowledge.

Level of UNDESD Awareness

The UNDESD is critical to sustainability literacy as it aimed at global implementation of sustainability education (UNESCO, 2005). Therefore, to appreciate the level of sustainability knowledge of a community, an inquiry into members' awareness of the UN declaration that sought to facilitate such knowledge is relevant. This can even be useful in testing the effectiveness of the now lapsed UN Decade. The survey results show that the Nigerian engineering community is largely oblivious of the Decade. There is evident widespread ignorance of the UN Decade within the engineering community in Nigeria. This finding is congruent with reports of poor awareness of several UN initiatives including MESA, ESD and UNDESD in most African countries (UNEP-MESA 2009; Manteaw 2012). The efficacy of the UNDESD in galvanising global support for sustainability education is therefore of concern; an observation also raised in the *UNDESD Final Report* (UNESCO, 2014).

Considering the degree of awareness of the Decade within the Nigerian engineering community, the level of success in engendering a sustainability literacy is obviously low. However, an interesting fact regarding the comparative levels of UNDESD awareness of the Nigerian engineering community is observed. Lack of UNDESD awareness is more widespread amongst students than amongst educators and practitioners. Although no explicit cause of this discrepancy can be readily ascertained, the educators conversant with the Decade may not have been informed by concerted sustainability education efforts; otherwise such awareness would have reflected on the students. Additionally, the almost equal level of UNDESD awareness between educators and practitioners suggests information sources other than HEIs, such as international conferences and global political debates platforms. Educators and practitioners have access to these fora which may typically elude the students. Consequently, sustainability literacy could be enhanced by increased participation in international conferences and access to global political issues.

Score on Sustainability Literacy Test

Sustainability literacy test provides a means of expressing the sustainability knowledge of an individual or community. The test is a recurring instrument for gauging sustainability literacy in sustainability education research (Zwickle *et al.*, 2014). Although there are no universally fixed questions on a sustainability quiz, the test is usually framed around sustainability themes and typically contextualised (Kieu *et al.*, 2016). The Nigerian engineering community performed poorly on the sustainability literacy test. The results of the test show no significant differences in the performance based on category, although practitioners performed slightly better than educators and students respectively. Nonetheless, across the sustainability topics, a notable disparity exists in the performance of the community. Practitioners evince relative strength in economic and social topics, whilst educators and students are strong in environmental and crosscutting themes respectively. Variation in topic familiarity is also noted with economic themes being the most familiar topics followed by social, environmental and crosscutting topics. The least known topics across the board are crosscutting issues; hence the need to emphasise them in an intervention.

Practical experience could account for the excelling of practitioners on the economic and social issues. In the course of executing various engineering works, practitioners typically deal with economic and sometimes social costs of a project. Such exposure to project development issues in real-world settings might explain the relatively good performance of the practitioners on the economic and social questions. Contrastingly, the reason for the difference in the performances of educators and students on the environmental and crosscutting questions is unclear. Perhaps educators are more cognisant of environmental concerns from interactions with their non-engineering environmental colleagues or from access to local environmental politics. Nevertheless, educators' skewed familiarity with environmental topics could not have resulted from any sustainability education efforts considering students' relatively poor performance on the theme. In the same vein, the outperformance of the students on the crosscutting questions may have been due to guesswork. Students' tendencies to ignore the '*don't know'* option on a *true/false/don't know* question format increases their chances of guessing some answers right. For the crosscutting questions, fewer students ticked the '*don't know'* option, which suggests that their relatively higher score on the theme could be mere serendipity.

Self-Assessment of Sustainability Knowledge

Self-assessment of sustainability knowledge enabled Nigerian engineering community to reflect on their sustainability knowledge with a view to offering an evaluation. Using the sustainability literacy test as a criterion, the self-assessment tool provided an opportunity to check test scores against perceived knowledge. Difference between perceived knowledge and actual knowledge is a recognised phenomenon in cognitive research (Brinol and Petty, 2012). Three theories for bias of knowledge self-assessment are self-esteem, frame of reference and personal relevance of the topic. With the exception of personal relevance which is positively correlated to actual knowledge, self-esteem and reference group have positive and negative correlations to actual knowledge (Radecki and Jaccard, 1995). A high self-esteem is likely to result in an overestimation of knowledge and vice versa. However, low self-esteem at times yields unwarranted knowledge claims in a process called defensive self-esteem mechanism. Reference affects perceived knowledge by contrast or assimilation. When individuals contrast their knowledge within a reference group, a claim to more knowledge is likely if the peer being compared to is deemed less informed; the converse is also true. Assimilation arises when people assert the knowledge level of their peers. The personal relevance theory assumes that personal importance of a topic heightens perceived knowledge.

In the case of Nigerian engineering community, self-rating of sustainability knowledge is averagely low. However, educators and practitioners claim greater knowledge of sustainability than students. This difference in sustainability knowledge perception can be explained by either the self-esteem or frame of reference theories. Explanation from personal relevance of the topic is ruled out as results show no significant relationship between sustainability import and perceived sustainability knowledge ($p \leq 0.05$). Although the self-esteem of Nigerian engineering community was not directly measured, it may explain the self-assurance manifest in educators' self-assessment of sustainability knowledge. Educators have a general tendency to exhibit high self-esteem (Mustaq *et al.*, 2012; Terra, Marziale and Robazzi, 2013) based on several factors including academic qualification. Since the minimum requirement for a lecturing position in Nigeria is a master's degree (BMAS, 2014), engineering educators might have been constrained to claim sustainability knowledge in justification of their educational status. With regards to practitioners' high estimation of their sustainability knowledge, the frame of reference theory could be at work. Lending credence to this assertion is the fact that participants for the practitioner category in the study were recruited mainly from professional associations and groups. Engineering professionals filling out a survey in the same room is an archetypal setting for assimilation effect, and may have influenced the sustainability self-assessment of the practitioner cohort.

Some Unexpected Findings

Low Familiarity with Environmental Topics

An unexpected outcome of the study is the low score on environmental questions featured in the sustainability literacy test. Studies have often reported environment as the most dominant sustainability theme in engineering education (Hanning *et al.*, 2012; Watson *et al.*, 2013; UNESCO, 2014). Furthermore, the fairly long-standing tradition of teaching environmental topics in Nigeria equally increased optimism in a positive outcome for the environmental themes. Thus, the lack of familiarity with contextual environmental issues shown by the Nigerian engineering community is unanticipated. However, it is possible that environmental education has been restricted to only environmental engineering students and not covered in the common courses. In this case, non-environmental students will not benefit from lessons on the environment. This might also explain the poor performance of the majority amongst educators and practitioners, being products of the same education system. This finding has important implication for sustainability education as it suggests the possibility of environmental issues not being adequately addressed by Nigerian engineers in the field. Hence, sustainability education intervention for Nigeria should not take environmental learning as a given in engineering curriculum.

Fewer Students Admit Adequate Sustainability Knowledge

Fewer students than expected claimed adequate knowledge of sustainability. This contrasts with findings of many studies which show that students, more often than not, overestimate their actual knowledge (Lundeberg *et al.*, 2000; Yadav *et al.*, 2011). Consequently, having about 8 in 10 students (81%) admitting inadequate sustainability knowledge is remarkable, but also reassuring. Students might have been persuaded to be more open about their sustainability knowledge by the apparent research objective of introducing sustainability into the Nigerian engineering education. This information might have encouraged them to genuinely admit ignorance of sustainability in the hope of benefiting from an introductory course on engineering sustainability. Indeed, the results of a sustainable engineering workshop survey conducted in the present research support this claim (*Chapter Ten*). This finding is important as it implies that students are willing to learn about sustainability. Thus, a sustainability education intervention for Nigerian engineering curriculum could draw strength from such potential.

Students' Sustainability Knowledge: Two Data Sets

In the study by Zwickle *et al* (2014) reviewed in the present research (see *Chapter Two*), the outcome of a sustainability test administered to a student population at The Ohio State University was presented. As previously stated, the test had a total average assessment score of 69%, which could be construed as the sustainability literacy of the students. The assessment scores for the economic, environmental and social domains were 71%, 73% and 61% respectively. There were significant differences in the performances of freshmen, sophomores and juniors. Of the three student groups, the freshmen were the least sustainability literate. It is noteworthy that a few of the questions posed to The Ohio State University students were equally featured on the sustainability test administered to the Nigerian engineering students. Precisely, Q1 - *Ozone layer protects us from acid rain and temperature fluctuations* and Q8 - *Long-term profitability is the most commonly used definition of economic sustainability* appeared on both tests. Consequently, comparing the results from the two data sets may provide some interesting insights.

In terms of general sustainability literacy and with a mean score of 20%, the Nigerian engineering students seem less knowledgeable than the students from The Ohio State University. Equally, twice as many Nigerian engineering students as The Ohio State University students provided the correct answers to the economic questions. Similarly, the percentage of the Nigerian students who answered the environmental questions correctly was one-third of the percentage of The Ohio State University students who did likewise. Furthermore, more Ohio State University students responded correctly to the social questions than the Nigerian engineering students. Since the crosscutting questions were not posed to the Ohio students, there is no basis for comparison with the Nigerian students. However, an interesting observation is made regarding the two questions (Q1 and Q8) which featured on both of the sustainability literacy tests. Whilst merely 10% of the Nigerian students answered Q1 correctly, an overwhelming 92.1% of the Ohio students provided the correct answer to the question. For Q8, more than half (51.7%) of the Nigerian students responded correctly, which is in contrast to the less than half (46.3%) of the Ohio students that answered the question correctly.

To make sense of these facts, it is instructive to note that the sample composition of The Ohio State University comprises both engineering and non-engineering students. The Nigerian sample consists strictly of engineering students. Although the sample sizes differ (Nigeria: n=232; Ohio: n=1,389), this may not be significant given the conventional sample size minimum requirement of n=100 for a 95% confidence level. In any event, the comparison between the two data sets demonstrates that there is, on average, a higher sustainability literacy amongst the students from The Ohio State University than amongst the Nigerian students. The involvement of non-engineering students from the Ohio State University may have influenced the outcome of the test. Social science students are likely to be more exposed to sustainability issues than engineering students. However, not all the sustainability concepts are familiar to the students of the US-based institution. Obviously, the Nigerian engineering students are more aware of some sustainability basics than The Ohio State University students as evidenced by their performance on Q8. Hence, sustainability education intervention should not proceed with the assumption that the students in the developed world are necessarily more sustainability literate than their counterparts in the rest of the world. The implication for Nigeria is that any means of intervention must be context-based.

Limitations

Some limitations are acknowledged in the study. One of these challenges involves the quantification of sustainability literacy based on level of UNDESD awareness. This cognisance gauge assumes that the 10-year global plan of educating the world for sustainability somehow influences sustainability literacy. Such association between sustainability literacy and level of UNDESD awareness may not be necessarily accurate. Often, people benefit from policy outcomes with whose guiding framework they are not conversant. Thus, it is conceivable for the engineering community in Nigeria to be sustainability literate without being aware of UNDESD. However, the chances of such occurrence in the community are quite slim as the results eventually showed: level of UNDESD awareness did not differ significantly from scores on the sustainability literacy test. Hence, UNDESD awareness is an appropriate contributor to sustainability literacy, and thus an important variable in the present study.

Another challenge of the study is limitation due to the constraints of the designed sustainability literacy test. As already highlighted in *Chapter Five*, the design of the sustainability literacy test was constrained by time and testable content. To achieve a balance between these factors, the '*true/false/don't know'* question format was adopted featuring some 15 questions across 4 sustainability themes. This questioning style is prone to guesswork, but useful for addressing a wide-range of issues and for examining conceptual knowledge (Building, 2017). Although the inclusion of '*don't know'* option had been intended to forestall conjecture, it is not a perfect countermeasure. Respondents can ignore the option and alternate arbitrarily between the *true* and *false* choices. However, such question-answering pattern was not observed in the data in any significant proportions. Additionally, focus on sustainability basics corresponds with the strength of the test format in aiding assessment of conceptual knowledge and consequently suitable for the study. Nonetheless, for examining deeper sustainability knowledge the online international sustainability literacy test, Sulitest (SLT, 2016) could be employed.

Summary

An assessment of the sustainability literacy of the Nigerian engineering community was conducted based on three criteria: level of UNDESD awareness; performance on a sustainability literacy test; and self-assessment of sustainability knowledge, and across three groups: students; educators; and practitioners. The categorical data resulting from these surveys were analysed and subsequently synthesised to holistically gauge the sustainability literacy level of Nigerian engineering community. From these analyses a number of findings ensued as presented and discussed in this chapter. Some of the main outcomes of the assessment are recapped.

Firstly, the Nigerian engineering community was found to generally exhibit a very low sustainability literacy with a significant majority (>70%) performing abysmally on all the assessment criteria. Secondly, there was an evidence of widespread ignorance of the UNDESD within the Nigerian engineering community with students being the most uniformed. Thirdly, Nigerian engineering community were more familiar with economic topics as more than two-fifths of them (42%) passed the economic questions featured on the sustainability literacy test. Fourthly, the least known sustainability themes across the board were the crosscutting issues. Finally, some unexpected findings of the study were little familiarity with environmental themes and sincerity of the students in admitting sustainability illiteracy.

Although, on the whole, the findings highlighted in this chapter indicate the need for a sustainability education intervention, it is crucial to assess the Nigerian engineering curriculum for its sustainability content. This will facilitate identification of sustainability knowledge gaps related to curricular content. To this end, the sustainability content of the Nigerian engineering curriculum is addressed in *Chapter Six*.

Chapter Six

6 Sustainability Content of Nigerian Engineering Curriculum

Introduction

This chapter addresses the question: *What is the sustainability content of the Nigerian engineering curriculum?* Answers to the question were derived from a documentary analysis of three engineering manuals including the BMAS document, and engineering handbooks of two Nigerian higher education institutions, labelled HEI-1 and HEI-2. Perspectives of engineering stakeholders in the HEIs (n=316) were equally sought to complement the documentary analysis. The documents and views were tested against *a priori* codes obtained from the expert-derived sustainability themes (*Chapter Four*). Underlying the assessments was whether sustainability topics were covered or mentioned in the engineering curriculum. The chapter proceeds by presenting results of the documentary analyses followed by those of the stakeholder surveys. The results are subsequently synthesised to estimate the sustainability content of the Nigerian engineering curriculum. The Nigerian engineering curriculum was subsequently contrasted with the UCL engineering curriculum. The chapter ends with a discussion of the findings and limitations of the study.

Engineering Documents

BMAS for Engineering

The BMAS document was analysed for its sustainability content based on 4 sustainability themes: economic, environmental, social and crosscutting topics. The results of the analysis are presented in the succeeding sections.

Economic Content

Figure 6.1 shows the spread of economic themes across 31 engineering programmes contained in the BMAS document. Only 12 programmes covered 5 of 6 economic topics with one economic theme, namely GNP, not mentioned in any of the programmes. There was no engineering programme that featured all the economic topics. However, the economic concept of *accountability* was covered in the common engineering courses. A recurring economic theme in the BMAS was *production & consumption patterns*. This theme occurred four times in chemical engineering courses and once each in agricultural, biomedical, civil, communications, gas, mechanical, and mining engineering as well as in petrochemical, petroleum, and wood products engineering courses. Hence, 16% of the potential BMAS economic content featured in the document, which corresponded to 0.65% of the BMAS (Table 6.1).

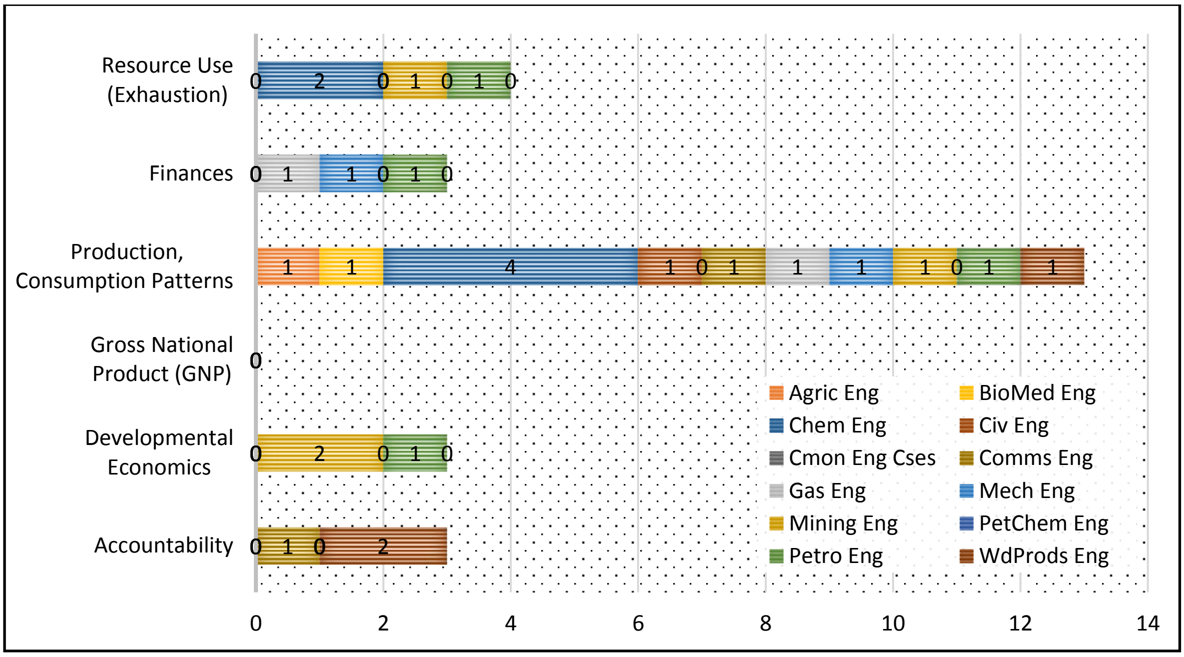


Figure 6.1. Economic content of BMAS document

Table 6.1. Descriptive statistics of BMAS economic content

Economic Concept	Frequency	Expected Occurrence	% within Potential Economic Content*	% within BMAS Document**
Accountability	5	31	16.13	0.20
Dev economics	3	31	9.67	0.14
Production patterns	13	31	41.93	0.34
Finances	4	31	12.90	0.11
Resource use	4	31	12.90	0.10
GNP	0	31	0.00	0.00
Economic content	29	186	15.59	0.65

* *(Frequency/Expected Occurrence) X 100*

*** Obtained directly from NVivo calculations as average of characters and page area percentages*

Environmental Content

The environmental content of the BMAS document is shown in Figure 6.2. Across the engineering programmes, 5 of 9 environmental themes featured in only 11 disciplines with environmental engineering covering up to 4 topics. Engineering disciplines which covered at least one of the 5 featured themes included civil, chemical, mechanical, mechatronics, and metallurgical engineering. Others were mining, petrochemical, petroleum, and public health engineering courses. Four environmental themes were completely absent in all of the programmes. *Pollution* was the prevalent environmental theme occurring 13 times in the document. The BMAS featured about 8% of the potential environmental content corresponding to 0.57% of the document (Table 6.2).

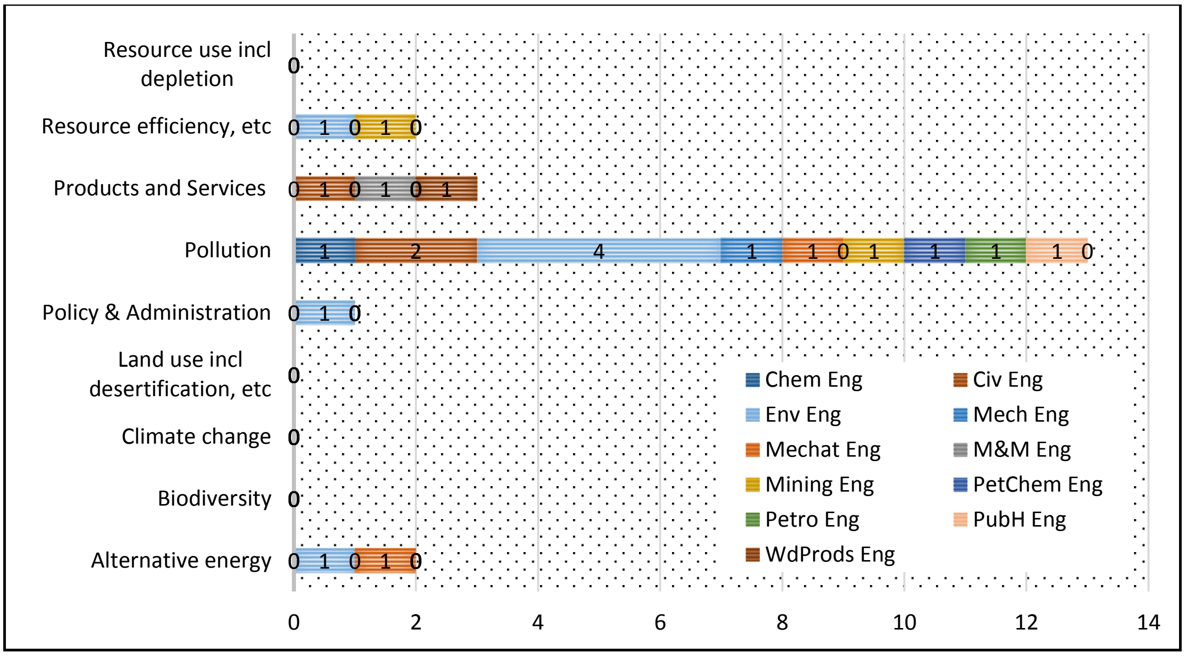


Figure 6.2. Environmental content of BMAS document

Table 6.2. Descriptive statistics of BMAS environmental content

Environmental Concept	Frequency	Expected Occurrence	% within Potential Environmental Content*	% within BMAS Document**
Alternative energy	2	31	6.45	0.08
Biodiversity	0	31	0.00	0.00
Climate change	0	31	0.00	0.00
Land use	0	31	0.00	0.00
Policy & admin	1	31	3.22	0.03
Pollution	13	31	41.94	0.43
Products & services	3	31	9.68	0.08
Resource efficiency	2	31	6.45	0.05
Resource depletion	0	31	0.00	0.00
Environmental content	21	279	7.53	0.57

** (Frequency/Expected Occurrence) X 100*

*** Obtained directly from NVivo calculations as average of characters and page area percentages*

Social Content

Figure 6.3 and Table 6.3 show the spread of the social concepts in the engineering programmes. Only 4 out of 12 social topics were mentioned in 9 programmes with *health & safety* being the most recurring theme. Eight social themes did not feature in any of the courses. Thus, just about 3% of the potential social content, which was equivalent to 0.45% of the BMAS document, featured in the engineering programmes.

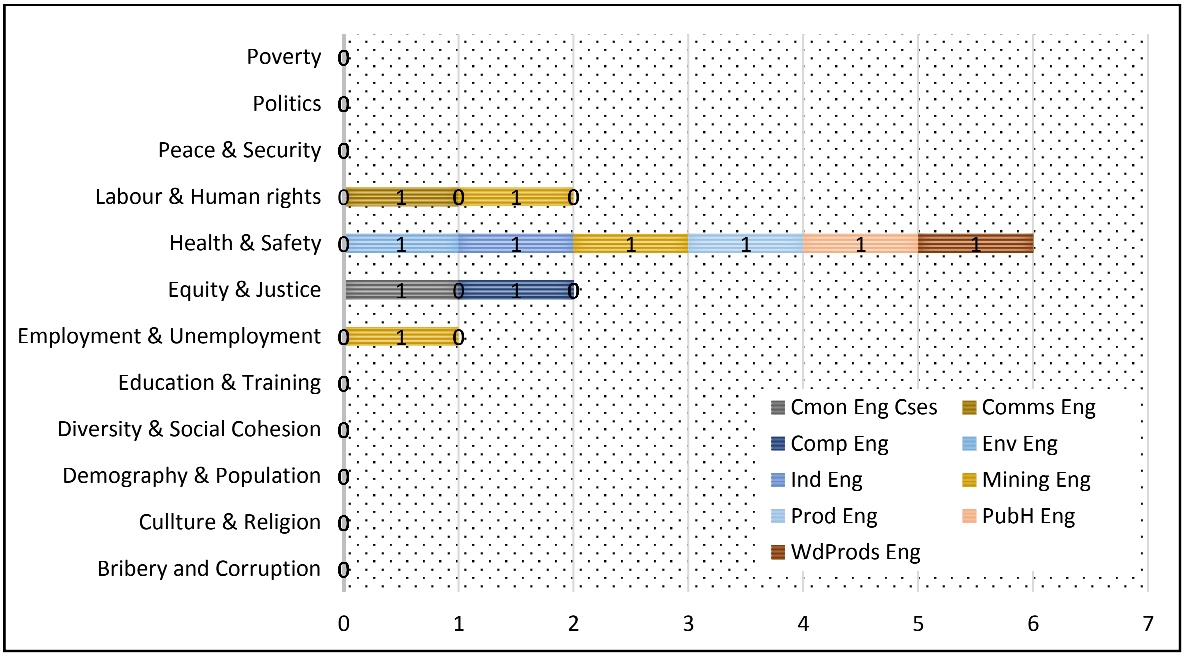


Figure 6.3. Social content of BMAS document

Table 6.3. Descriptive statistics of BMAS social content

Social Concept	Frequency	Expected Occurrence	% within Potential Social Content*	% within BMAS Document**
Bribery & corruption	0	31	0.00	0.00
Culture & religion	0	31	0.00	0.00
Demography	0	31	0.00	0.00
Diversity & cohesion	0	31	0.00	0.00
Education and training	0	31	0.00	0.00
Employment	1	31	3.22	0.06
Equity & justice	2	31	6.45	0.15
Health & safety	6	31	19.35	0.16
Labour & human right	2	31	6.45	0.14
Peace & security	0	31	0.00	0.05
Politics	0	31	0.00	0.00
Poverty	0	31	0.00	0.00
Social content	11	372	2.96	0.45

** (Frequency/Expected Occurrence) X 100* *** Obtained directly from NVivo calculations as average of characters and page area percentages*

Crosscutting Content

The distribution of the crosscutting themes within the BMAS involved 7 engineering disciplines as shown in Figure 6.4. Only 4 of 10 cross-cutting topics were addressed. The themes of *communication, reporting, ethics & philosophy* featured most frequently in the programmes. Six cross-cutting themes did not appear in any of the courses. Hence, 6% of the potential crosscutting content corresponding to 0.45% of the BMAS was covered in the document (Table 6.4).

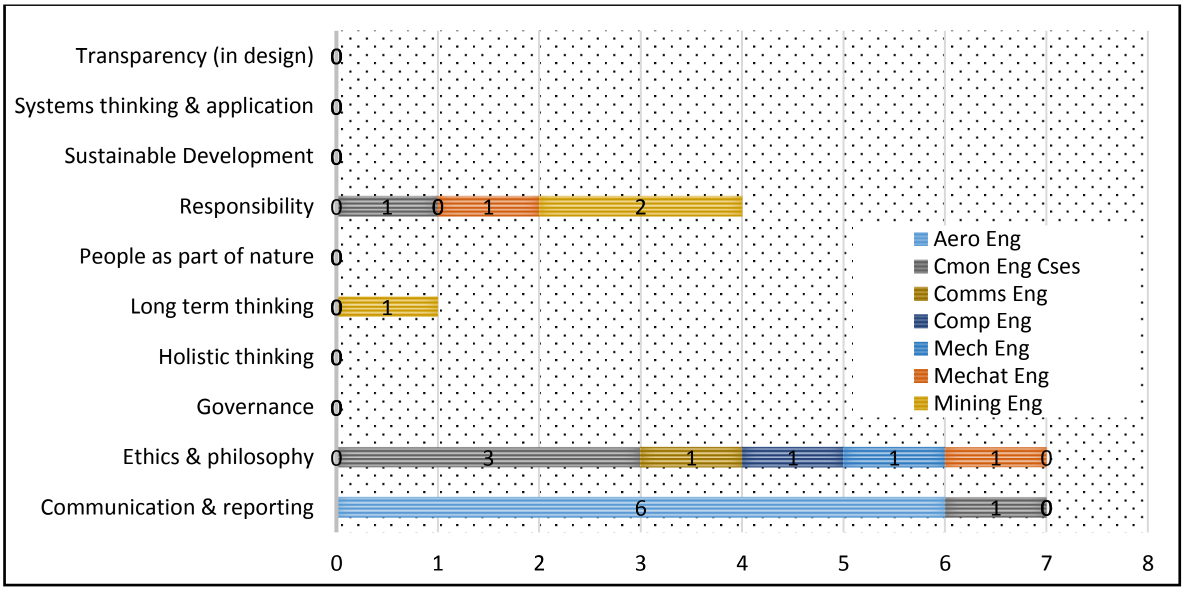


Figure 6.4.Crosscutting content of BMAS document

Table 6.4. Descriptive statistics of crosscutting content

Crosscutting Concept	Frequency	Expected Occurrence	% within Potential Cross-cutting Content*	% within BMAS Document**
Comm & reporting	7	31	22.58	0.05
Ethics & philosophy	7	31	22.58	0.25
Governance	0	31	0.00	0.00
Holistic thinking	0	31	0.00	0.00
Long-term thinking	1	31	3.22	0.14
People: part of nature	0	31	0.00	0.00
Responsibility	4	31	12.90	0.21
Sustainability	0	31	0.00	0.00
Systems thinking	0	31	0.00	0.00
Transparency: design	0	31	0.00	0.00
Crosscutting content	19	310	6.13	0.48

* (*Frequency/Expected Occurrence) X 100*

*** Obtained directly from NVivo calculations as average of characters and page area percentages*

BMAS Sustainability Content

The sustainability content of the BMAS can be determined by collating the results from the analysis of the sustainability themes (Table 6.5). The results showed that the BMAS document had, on average, an extremely low sustainability content. Achieving only 8% of its potential coverage and contained in merely 2% of the entire document, sustainability theme did not receive much attention in the BMAS for engineering. However, economic topics were mentioned more than environmental, crosscutting and social themes respectively. Social issues were the least addressed themes in the BMAS document. Additionally, there was no engineering programme that featured all the subtopics of the sustainability themes.

Table 6.5. Sustainability coverage of BMAS document

Theme	Engineering Programme Featured	% within Potential	%BMAS Coverage
Economic	Agricultural, biomedical, chemical, civil, communications, gas, mechanical, mining, petrochemical, petroleum, wood products, common courses.	15.59	0.65
Environmental	Chemical, civil, environmental, mechanical, mechatronics, metallurgical, mining, petrochemical, petroleum, public health, wood products.	7.53	0.57
Social	Communications, computer, environmental, industrial, mining, productions, public health, wood products, common courses.	2.96	0.45
Crosscutting	Aerospace, communications, computer, mechanical, mechatronics, mining, common courses	6.13	0.48
Sustainability	Mean	**8.05**	Total **2.15**

HEI-1 Engineering Handbook

HEI-1 is a federal university in Nigeria offering 10 engineering programmes domiciled in seven departments and also features common courses. The results of the sustainability content analysis of its engineering handbook are presented below.

Economic Content

The economic content of the HEI-1 engineering handbook was spread across 6 engineering programmes as shown in Figure 6.5. The most frequently mentioned economic theme was *production & consumption patterns,* which occurred five times within three disciplines: chemical, electrical/electronic and mechanical engineering. Two themes, namely *GNP* and *resource use & efficiency* were not contained in any of the engineering programmes. None of the programmes featured more than two themes, although *accountability* and *developmental economics* were addressed in the common courses. Nonetheless, from Table 6.6, about 18% of the potential economic content was covered in the handbook, which corresponded to 1.60% of the entire engineering document. Thus, the HEI-1 engineering handbook had a somewhat fair economic content.

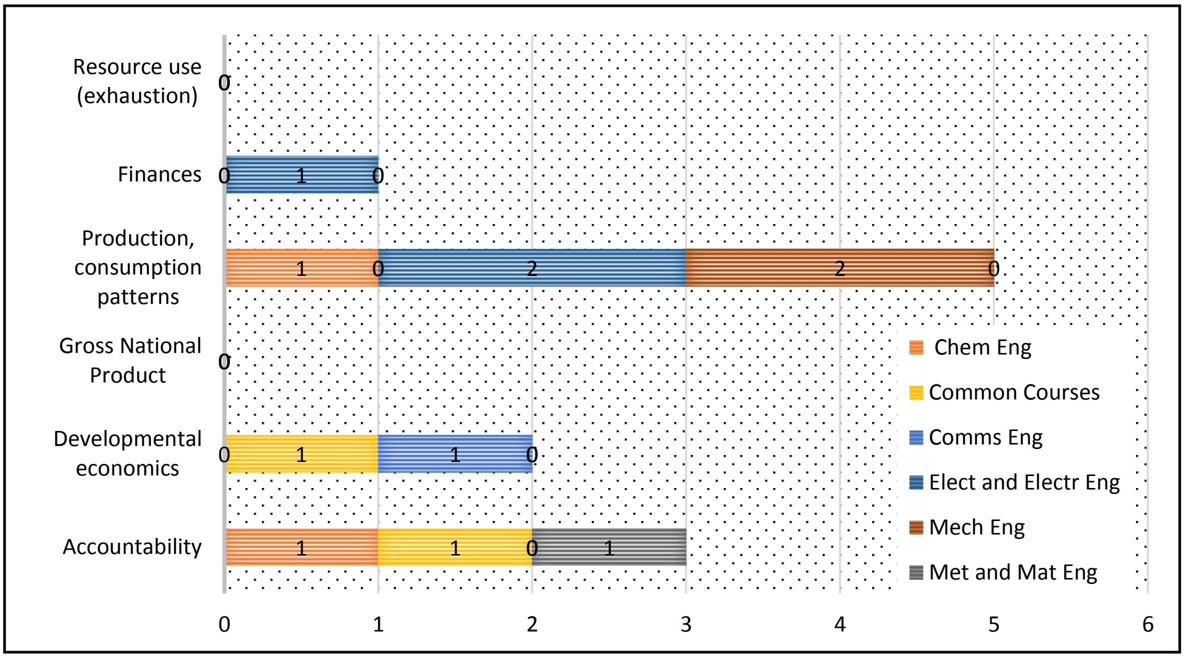


Figure 6.5. Economic content of HEI-1 engineering handbook

Table 6.6. Descriptive statistics of HEI-1 handbook economic content

Economic Concept	Frequency	Expected Occurrence	% within Potential Economic Content*	% within HEI-1 Handbook**
Accountability	3	10	30.00	0.43
Dev economics	2	10	20.00	0.04
Production patterns	5	10	50.00	0.91
Finances	1	10	10.00	0.21
Resource use	0	10	0.00	0.00
GNP	0	10	0.00	0.00
Economic content	11	60	18.33	1.60

* *(Frequency/Expected Occurrence) X 100* *** Obtained directly from NVivo calculations as average of characters and page area percentages*

Environmental Content

Spread of the environmental concepts in the HEI-1 engineering handbook occurred across 7 engineering programmes as indicated in Figure 6.6. The themes of *resource use, energy & water* and *alternative energy* were prevalent in the engineering manual. However, 4 of 9 environmental themes did not appear in any of the programmes. The exclusions were *climate change, resource ecoefficiency, biodiversity* and *products & toxic wastes*. Interestingly, environmental engineering, even though, covered all the 5 featured themes, also failed to include the three omissions. Overall, a significant part of the potential environmental content (31%), equivalent to 4% of the engineering handbook, was attained in the document (Table 6.7).

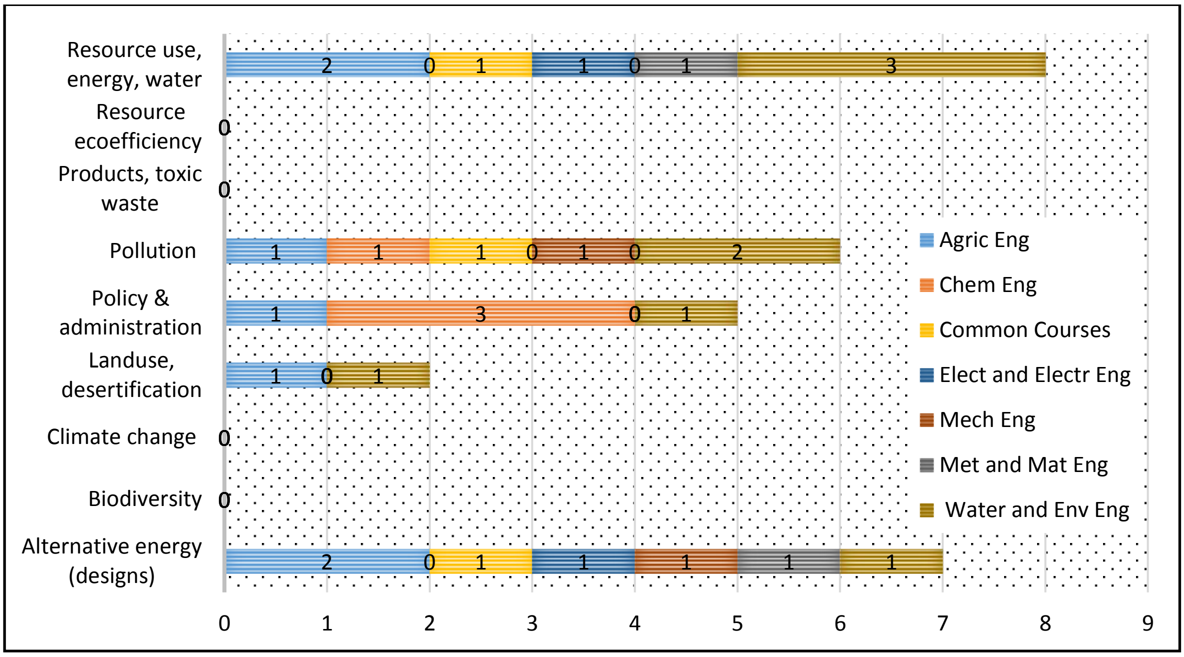


Figure 6.6. Environmental content of HEI-1 engineering handbook

Table 6.7. Descriptive statistics of HEI-1 handbook environmental content

Environmental Concept	Frequency	Expected Occurrence	% within Potential Environmental Content*	% within HEI-1 Handbook**
Alternative energy	7	10	70.00	0.46
Biodiversity	0	10	0.00	0.00
Climate change	0	10	0.00	0.00
Land use	2	10	20.00	0.28
Policy & admin	5	10	50.00	0.32
Pollution	6	10	60.00	1.31
Products & services	0	10	0.00	0.00
Resource efficiency	0	10	0.00	0.00
Resource depletion	8	10	80.00	1.13
Environmental content	28	90	31.11	3.55

** (Frequency/Expected Occurrence) X 100*

*** Obtained directly from NVivo calculations as average of characters and page area percentages*

Social Content

The results of the social content of the HEI-1 engineering handbook are presented in Figure 6.7 and Table 6.8. With the exception of *health & safety* and *employment*, no social topic was mentioned in the handbook. These 2 of 12 social themes were covered in 6 engineering programmes with only electrical and electronics engineering featuring employment issues. In general, the social content of the HEI-1 engineering handbook was quite low with merely 5% of its potential attained, which equated to about 1% of the whole engineering document.

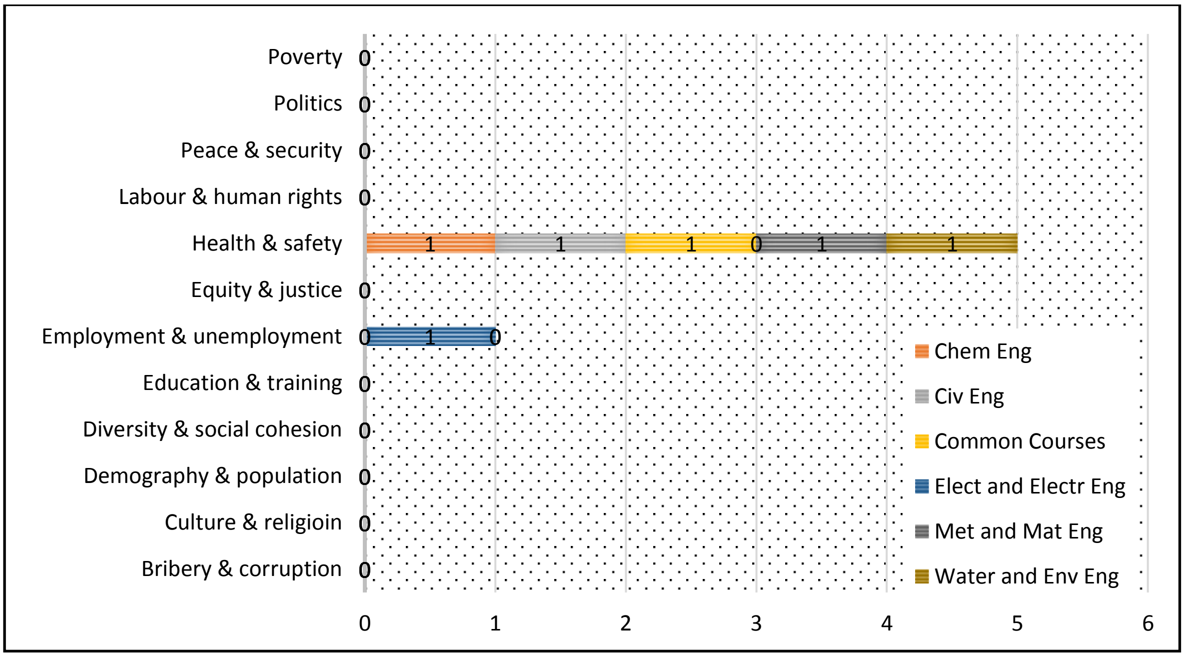


Figure 6.7. Social content of HEI-1 engineering handbook

Table 6.8. Descriptive statistics of HEI-1 handbook social content

Social Concept	Frequency	Expected Occurrence	% within Potential Social Content*	% within HEI-1 Handbook**
Bribery & corruption	0	10	0.00	0.00
Culture & religion	0	10	0.00	0.00
Demography	0	10	0.00	0.00
Diversity & cohesion	0	10	0.00	0.00
Education and training	0	10	0.00	0.00
Employment	1	10	10.00	0.16
Equity & justice	0	10	0.00	0.00
Health & safety	5	10	50.00	0.98
Labour & human right	0	10	0.00	0.00
Peace & security	0	10	0.00	0.00
Politics	0	10	0.00	0.00
Poverty	0	10	0.00	0.00
Social content	6	120	5.00	1.13

* *(Frequency/Expected Occurrence) X 100*   ** *Obtained directly from NVivo calculations as average of characters and page area percentages*

Crosscutting Content

Crosscutting concepts were spread across 7 fields in the HEI-1 engineering handbook (Figure 6.8 and Table 6.9). However, only half of the themes were mentioned with *communication & reporting* and *ethics & philosophy* being prevalent. Three of the featured themes appeared in the common courses whilst 4 topics were contained in metallurgical engineering. Generally, the crosscutting theme had 15% of its potential content, corresponding to 0.85% of the entire engineering handbook, covered.

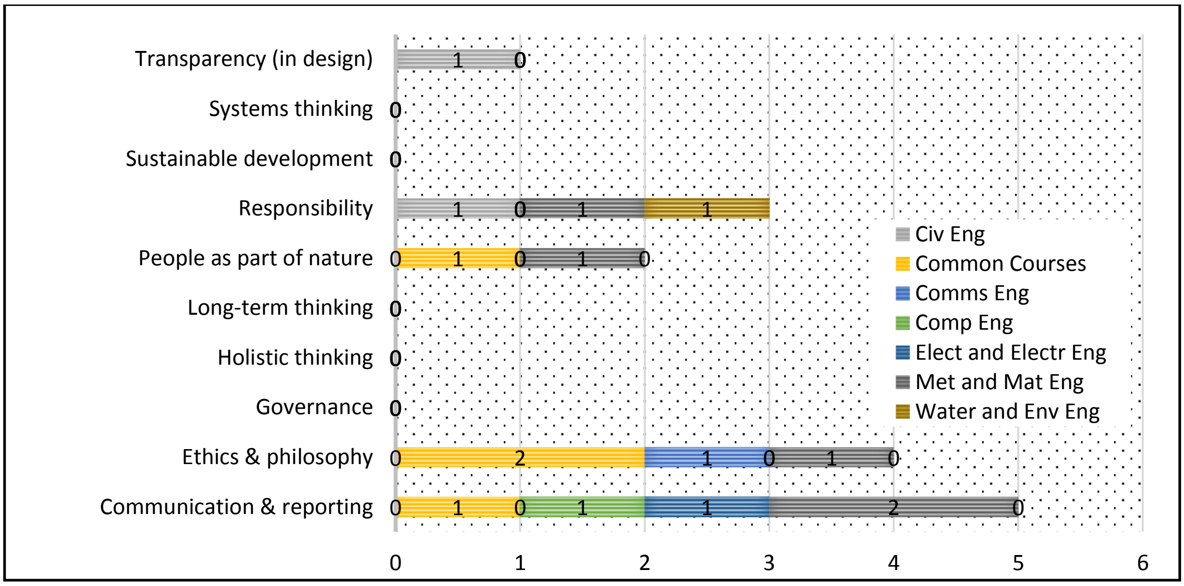


Figure 6.8. Crosscutting content of HEI-1 engineering handbook

Table 6.9. Descriptive statistics of HEI-1 handbook crosscutting content

Cross-cutting Concept	Frequency	Expected Occurrence	% within Potential Cross-cutting Content*	% within HEI-1 Handbook**
Comm & reporting	5	10	50.00	0.38
Ethics & philosophy	4	10	40.00	0.14
Governance	0	10	0.00	0.00
Holistic thinking	0	10	0.00	0.00
Long-term thinking	0	10	0.00	0.00
People: part of nature	2	10	20.00	0.01
Responsibility	3	10	30.00	0.27
Sustainability	0	10	0.00	0.00
Systems thinking	0	10	0.00	0.00
Transparency: design	1	10	10.00	0.15
Crosscutting content	15	100	15.00	0.85

* *(Frequency/Expected Occurrence) X 100* ** *Obtained directly from NVivo calculations as average of characters and page area percentages*

HEI-1 Engineering Handbook Sustainability Content

Table 6.10 presents a summary of the sustainability content of HEI-1 engineering handbook. The results showed that the engineering handbook had a generally low sustainability content with just 17% potential attained, i.e. 7% of the HEI-1 engineering handbook. Nonetheless, environmental themes were the most frequently mentioned topics accounting for half of the document's sustainability coverage. In addition, the crosscutting themes had the least coverage (0.85%), but the social concepts were the least dispersed across the disciplines. Interestingly, metallurgical & materials engineering featured at least one subtheme of all the sustainability themes.

Table 6.10. Sustainability coverage of HEI-1 engineering handbook

Theme	Engineering Programme Featured In	% within Potential	%HEI-1 Coverage
Economic	Chemical, communications, electrical/electronics, mechanical, metallurgical/materials, common courses	18.33	1.60
Environmental	Agricultural, chemical, electrical/electronics, mechanical, metallurgical/materials, water & environmental, common courses	31.11	3.55
Social	Chemical, civil, electrical/electronics, metallurgical/materials, water & environmental, common courses	5.00	1.13
Crosscutting	Civil, communications, computer, electrical/electronics, metallurgical/materials, water & environmental, common courses	15.00	0.85
Sustainability	Mean	**17.36**	Total **7.13**

HEI-2 Engineering Handbook

HEI-2 is a higher education institution in Nigeria which offers three engineering programmes. The succeeding sections present the results of the sustainability content analysis of the institution's engineering handbook.

Economic Content

Economic concepts were poorly featured in the HEI-2 engineering handbook as shown in Figure 6.9 and Table 6.11. Only the subtheme of *accountability* was contained in the document by two disciplines, namely civil and electrical/electronic engineering, and the common courses. Based on the potential economic content of the curriculum, only a fraction (12%), corresponding to 0.60% of the document, was featured.

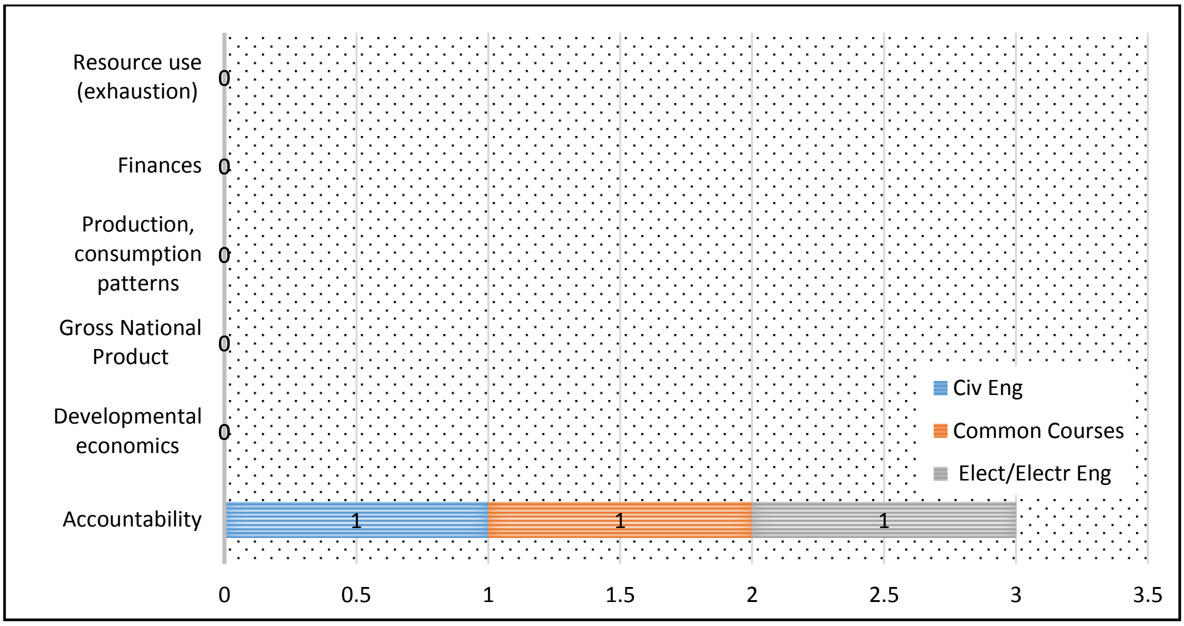


Figure 6.9. Economic content of HEI-2 engineering handbook

Table 6.11. Descriptive statistics of HEI-2 handbook economic content

Economic Concept	Frequency	Expected Occurrence	% within Potential Economic Content*	% within HEI-2 Handbook**
Accountability	3	4	75.00	0.60
Dev economics	0	4	0.00	0.00
Production patterns	0	4	0.00	0.00
Finances	0	4	0.00	0.00
Resource use	0	4	0.00	0.00
GNP	0	4	0.00	0.00
Economic content	3	24	12.5	0.60

* *(Frequency/Expected Occurrence) X 100*

*** Obtained directly from NVivo calculations as average of characters and page area percentages*

Environmental Content

The distribution of environmental themes in the HEI-2 engineering handbook occurred across two disciplines as indicated in Figure 6.10. Four of 9 environmental themes featured chiefly in civil engineering courses with only *resource use, energy & water* mentioned in electrical & electronics engineering. Overall, the environmental coverage of the engineering handbook was low at 14% potential content and 1% of the document (Table 6.12).

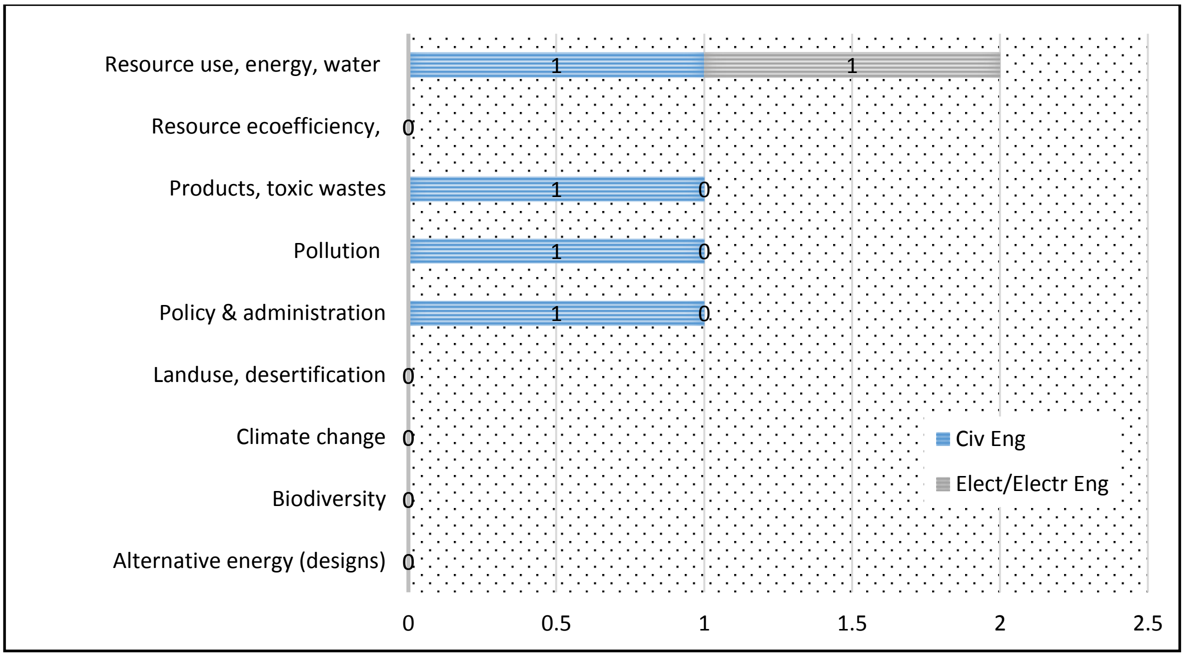


Figure 6.10. Environmental content of HEI-2 engineering handbook

Table 6.12. Descriptive statistics of HEI-2 handbook environmental content

Environmental Concept	Frequency	Expected Occurrence	% within Potential Environmental Content*	% within HEI-2 Handbook**
Alternative energy	0	4	0.00	0.00
Biodiversity	0	4	0.00	0.00
Climate change	0	4	0.00	0.00
Land use	0	4	0.00	0.00
Policy & admin	1	4	25.00	0.17
Pollution	1	4	25.00	0.14
Products & services	1	4	25.00	0.20
Resource ecoefficiency	0	4	0.00	0.00
Resource depletion	2	4	50.00	0.76
Environmental content	5	36	13.88	1.06

* *(Frequency/Expected Occurrence) X 100*

** *Obtained directly from NVivo calculations as average of characters and page area percentages*

Social Content

The HEI-2 engineering handbook featured 3 of 12 social themes (Figure 6.11). Only civil engineering and common courses contained these topics. Thus, the social coverage of the engineering handbook was low as just 12% of its potential content (equivalent to 0.66% of the handbook) was attained (Table 6.13).

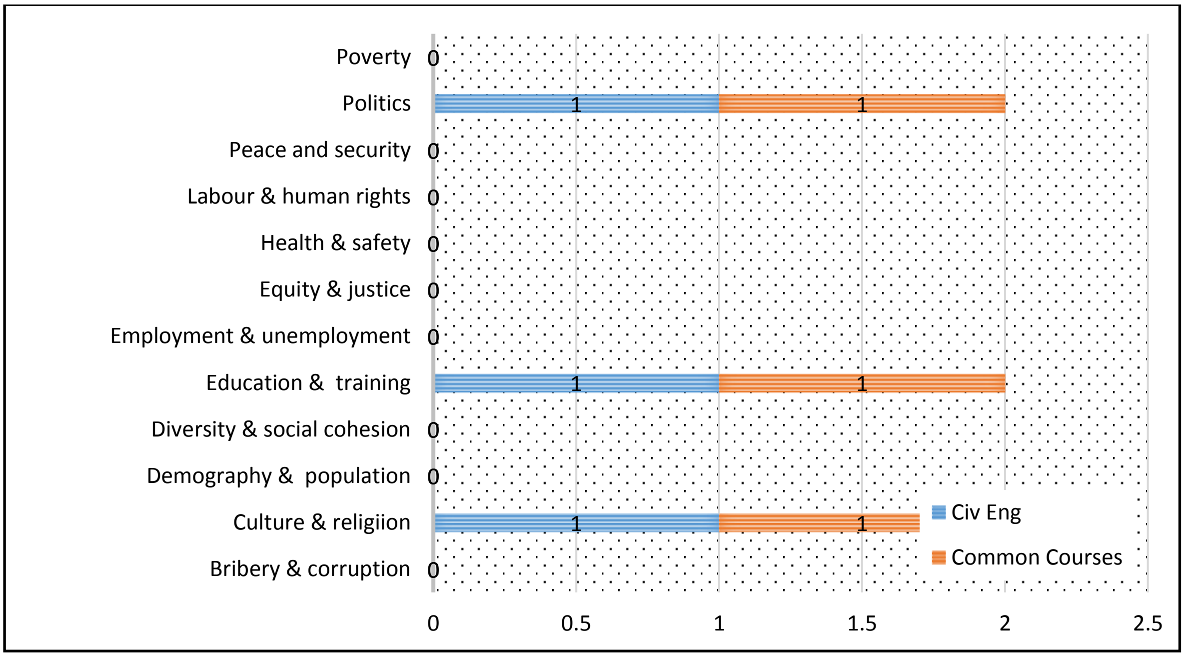


Figure 6.11. Social content of HEI-2 engineering handbook

Table 6.13. Descriptive statistics of HEI-2 handbook social content

Social Concept	Frequency	Expected Occurrence	% within Potential Social Content*	% within HEI-2 Handbook**
Bribery & corruption	0	4	0.00	0.00
Culture & religion	2	4	50.00	0.20
Demography	0	4	0.00	0.00
Diversity & cohesion	0	4	0.00	0.00
Education and training	2	4	50.00	0.15
Employment	0	4	0.00	0.00
Equity & justice	0	4	0.00	0.00
Health & safety	0	4	0.00	0.00
Labour & human right	0	4	0.00	0.00
Peace & security	0	4	0.00	0.00
Politics	2	4	50.00	0.30
Poverty	0	4	0.00	0.00
Social content	6	48	12.50	0.66

** (Frequency/Expected Occurrence) X 100*

*** Obtained directly from NVivo calculations as average of characters and page area percentages*

Crosscutting Content

Four crosscutting themes spread across the four engineering programmes contained in HEI-2 engineering handbook as indicated in Figure 6.12. The subtheme of *ethics & philosophy* recurred in all the programmes. In terms of potential content, the crosscutting themes attained about one-fifth (20%) coverage corresponding to 1.33% of the whole engineering handbook (Table 6.14).

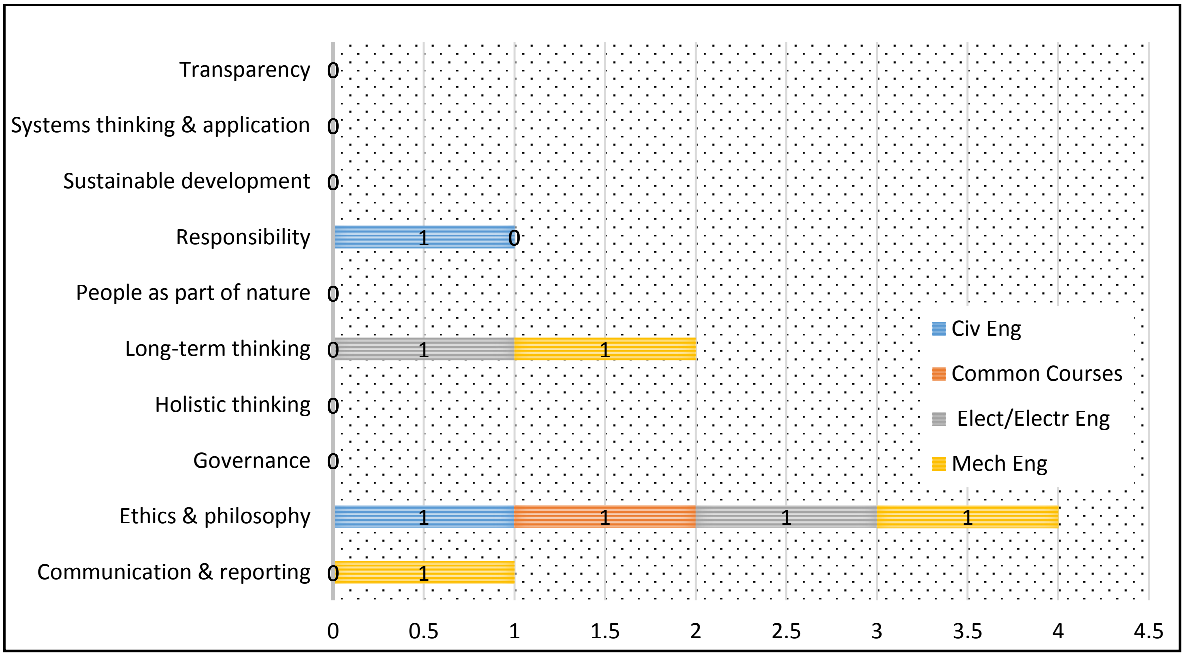


Figure 6.12. Crosscutting content of HEI-2 engineering handbook

Table 6.14. Descriptive statistics of HEI-2 handbook crosscutting content

Crosscutting Concept	Frequency	Expected Occurrence	% within Potential Cross-cutting Content*	% within HEI-2 Handbook**
Comm & reporting	1	4	25.00	0.05
Ethics & philosophy	4	4	100.00	0.66
Governance	0	4	0.00	0.00
Holistic thinking	0	4	0.00	0.00
Long-term thinking	2	4	50.00	0.19
People: part of nature	0	4	0.00	0.00
Responsibility	1	4	25.00	0.42
Sustainable dev	0	4	0.00	0.00
Systems thinking	0	4	0.00	0.00
Transparency: design	0	4	0.00	0.00
Crosscutting content	8	40	20.00	1.33

* *(Frequency/Expected Occurrence) X 100*

** *Obtained directly from NVivo calculations as average of characters and page area percentages*

HEI-2 Engineering Handbook Sustainability Content

Table 6.15 presents a summary of the sustainability content of HEI-2 engineering handbook. The results showed that the engineering handbook had a generally low sustainability content barely attaining 15% of its potential content, equivalent to 4% of the engineering document. However, crosscutting themes were the most recurring topics with subthemes cited in all three engineering programmes including the common engineering courses. The discipline of mechanical engineering featured only one subtheme of the crosscutting concepts.

Table 6.15. Sustainability coverage of HEI-2 engineering handbook

Theme	Engineering Programme Featured In	% within Potential	%HEI-2 Coverage
Economic	Civil, electrical & electronics engineering, common courses	12.50	0.60
Environmental	Civil, electrical & electronics engineering	13.88	1.06
Social	Civil, common courses	12.50	0.66
Crosscutting	Civil, electrical & electronics, mechanical, common courses	20.00	1.33
Sustainability	Mean	**14.72**	Total **3.65**

Stakeholder Views

Perception of students and educators on the sustainability content of the engineering curriculum operated in their HEIs was analysed. The results of the analysis are presented in the succeeding sections. The five responses featured on the Likert scale, namely *not at all*, *slightly*, *moderately*, *strongly* and *to a great extent* were reduced to three categories and notated thus: $\phi_{1\text{-}2}$ = *"not at all"* and *"slightly"* responses; ϕ_3 = *"moderately"* responses, and $\phi_{4\text{-}5}$ = *"strongly"* and *"to a great extent"* responses.

HEI-1 Student Perception (n=137)

A total of 137 engineering students of HEI-1 responded to the curricular sustainability content questions. The survey sought the opinions of the students on the economic, environmental, social and crosscutting contents of the engineering curriculum used in their institution.

Economic Content

Results showed that HEI-1 engineering students had varied views about the coverage of economic concepts in the engineering courses (Table 6.16). Nearly half of the students (45.7%) were convinced that *resource use* was covered "strongly" or "to a great extent" in engineering lessons. However, *GNP* was perceived as the least addressed economic theme in the curriculum as over half of the students (57.3%) stated that the subtheme was either "not included at all" or "slightly" mentioned. Overall, one-third of the students (33%) considered economic sustainability concepts as adequately addressed in the engineering courses.

Table 6.16. HEI-1Student perspective on curricular economic content

Economic Theme	$\phi_{1\text{-}2}$ (%)	ϕ_{3} (%)	$\phi_{4\text{-}5}$ (%)
Accountability	38.0	32.5	29.5
Dev economics	31.0	29.5	39.5
Production patterns	28.7	38.0	33.4
Finances	34.1	31.0	34.9
Resource use	23.3	31.0	45.7
GNP	57.3	27.9	14.8
Mean	**35.4**	**31.7**	**33.0**

Note: $\phi_{1\text{-}2}$ signifies "not at all" and "slightly" responses, ϕ_{3} represents "moderately", while $\phi_{4\text{-}5}$ symbolises "strongly" and "to a great extent" responses

Environmental Content

HEI-1 engineering students viewed the environmental content of engineering courses variously (Table 6.17). The most recognised environmental themes were *pollution* and *policy & admin* with two-fifths (41%) of the students suggesting a "strong" or "to a great extent" inclusion. Conversely, the engineering students considered the subthemes of *biodiversity*, *climate change* and *alternative energy* as least addressed topics in engineering lectures. On average, a little over one-third of the students (33.9%) thought that environmental topics were seriously addressed in the engineering curriculum.

Table 6.17 HEI-1Student perspective on curricular environmental content

Environmental Theme	ϕ_{1-2} (%)	ϕ_3 (%)	ϕ_{4-5} (%)
Alternative energy	38.2	23.4	38.4
Biodiversity	48.1	24.0	27.9
Climate change	38.8	29.5	31.8
Land use	37.3	26.4	36.3
Policy & admin	30.4	28.1	41.5
Pollution	28.7	30.2	41.1
Products & services	41.9	33.3	24.8
Resource ecoefficiency	37.8	35.4	26.8
Resource depletion	25.8	37.5	36.7
Mean	**36.3**	**29.8**	**33.9**

Note: ϕ_{1-2} signifies "not at all" and "slightly" responses, ϕ_3 represents "moderately", while ϕ_{4-5} symbolises "strongly" and "to a great extent" responses

Social Content

Perception of HEI-1 engineering students on the incorporation of social concepts in engineering courses was diverse, but significantly skewed towards non-inclusion (Table 6.18). A sizeable number of students thought that nearly all the subthemes of the social concept were either "slightly" or completely excluded from the courses. In particular, over half of the students opined that *culture & religion* (56%), *bribery & corruption* (52%) and *poverty* (51%) were not addressed in engineering lectures. Only the subtheme of *education & training* was considered by a good proportion of the students (39%) as reasonably addressed in the courses. Overall, almost half of the HEI-1 engineering students (46%) perceived the social content of engineering lectures as very poor.

Table 6.18 HEI-1Student perspective on curricular social content

Social Concept	ϕ_{1-2} (%)	ϕ_3 (%)	ϕ_{4-5} (%)
Bribery & corruption	52.0	26.4	21.6
Culture & religion	56.6	24.0	19.4
Demography	48.8	28.7	26.8
Diversity & cohesion	50.4	34.9	14.7
Education and training	33.3	27.9	38.7
Employment	44.2	27.9	27.9
Equity & justice	45.0	34.0	21.0
Health & safety	30.2	37.2	32.6
Labour & human right	48.1	34.1	17.8
Peace & security	44.2	28.7	27.1
Politics	43.5	34.1	22.4
Poverty	51.2	27.1	21.7
Mean	**45.6**	**30.4**	**24.3**

Note: ϕ_{1-2} signifies "not at all" and "slightly" responses, ϕ_3 represents "moderately", while ϕ_{4-5} symbolises "strongly" and "to a great extent" responses

Crosscutting Content

Views on the crosscutting content of engineering lectures at HEI-1 varied amongst engineering students (Table 6.19). For instance, a good proportion of the students (39%) indicated that *sustainable development* was either "strongly" addressed or mentioned "to a great extent" in the lectures. Such positive view, however, was not held for the remaining crosscutting themes. Over half of the students (54%) signified failure to learn much about *people as part of nature* from the engineering lessons. Other subthemes of the crosscutting topic which were also poorly acknowledged by a good number of the students included *holistic thinking* (48%), *ethics& philosophy* (39.5%) *communication & reporting* (38.8%), and *systems thinking* (38%). On the whole, 4 in 10 students (40%) expressed low opinion of the crosscutting content of the engineering courses.

Table 6.19. HEI-1Student perspective on curricular crosscutting content

Crosscutting Concept	ϕ_{1-2} (%)	ϕ_3 (%)	ϕ_{4-5} (%)
Comm & reporting	38.8	28.7	32.5
Ethics & philosophy	39.5	34.9	25.6
Governance	40.3	43.4	16.3
Holistic thinking	48.1	28.3	23.6
Long-term thinking	37.2	28.7	34.1
People: part of nature	53.5	31.0	15.5
Responsibility	40.4	30.2	29.4
Sustainable dev	29.5	31.8	38.7
Systems thinking	38.0	43.4	18.6
Transparency: design	38.8	28.7	32.5
Mean	**40.4**	**32.9**	**26.7**

Note: ϕ_{1-2} signifies "not at all" and "slightly" responses, ϕ_3 represents "moderately", while ϕ_{4-5} symbolises "strongly" and "to a great extent" responses

HEI-1 Educator Perception (n=55)

Fifty-five engineering educators at HEI-1 participated in the curricular sustainability survey. The succeeding sections present the results of the survey expressed in terms of economic, environmental, social and crosscutting contents of engineering courses.

Economic Content

HEI-1 engineering educators expressed differing views on the economic content of engineering courses at the institution (Table 6.20). More than half of the engineering educators suggested that *resource use* (58%) and *production & consumption patterns* (51%) were addressed "strongly" or "to a great extent" in engineering lectures. *Developmental economics* was least acknowledged with a significant proportion of the educators (43.6%) indicating that the subtheme was either "slightly" mentioned or "not at all" discussed in engineering lessons. Nonetheless, a sizeable number of the engineering educators (40.9%) expressed a strongly positive view of the economic content of the engineering courses.

Table 6.20. HEI-1 Educator perspective on curricular economic content

Economic Theme	ϕ_{1-2} (%)	ϕ_3 (%)	ϕ_{4-5} (%)
Accountability	38.2	20.0	41.8
Dev economics	43.6	27.3	29.1
Production patterns	30.9	18.2	50.9
Finances	34.5	29.1	36.4
Resource use	21.8	20.0	58.2
GNP	34.5	36.4	29.1
Mean	**33.9**	**25.2**	**40.9**

Note: ϕ_{1-2} signifies "not at all" and "slightly" responses, ϕ_3 represents "moderately", while ϕ_{4-5} symbolises "strongly" and "to a great extent" responses

Environmental Content

There was a difference of opinion amongst the engineering educators at HEI-1 on the environmental content of engineering courses (Table 6.21). However, a relatively positive outlook prevailed in the perceived coverage of the environmental themes. Almost two-thirds of the educators (60%) considered the subtheme of *resource depletion* as strongly addressed in engineering lectures. Similarly, the subtopic of *alternative energy* was viewed as adequately covered by over half of the engineering educators (54.5%). Nevertheless, *biodiversity* and *land use* subthemes were largely unacknowledged by the educators with half (48%) and two-fifths (38%) of them opting for either "slightly" or "not at all" responses respectively. Overall, the outlook of engineering educators on the environmental content of engineering courses at HEI-1 was somewhat optimistic at 45% perceived coverage.

Table 6.21. HEI-1 Educator perspective on curricular environmental content

Environmental Theme	$\phi_{1\text{-}2}$ (%)	ϕ_3 (%)	$\phi_{4\text{-}5}$ (%)
Alternative energy	20.0	25.5	54.5
Biodiversity	41.8	20.0	38.2
Climate change	36.4	18.2	45.4
Land use	38.2	23.6	38.2
Policy & admin	36.4	20.0	43.6
Pollution	25.5	32.7	41.8
Products & services	32.8	25.4	41.8
Resource ecoefficiency	30.9	23.6	45.5
Resource depletion	25.5	14.5	60.0
Mean	**31.9**	**22.6**	**45.4**

Note: $\phi_{1\text{-}2}$ signifies "not at all" and "slightly" responses, ϕ_3 represents "moderately", while $\phi_{4\text{-}5}$ symbolises "strongly" and "to a great extent" responses

Social Content

HEI-1 engineering educators viewed the social content of engineering courses differently (Table 6.22). Over half of the educators (56.4%) admitted strong treatment or coverage of *education & training* in engineering lessons. Not less than forty percent (40%) of the educators considered the subthemes of *bribery & corruption* and *culture & religion* as poorly addressed in the courses. In addition, almost half of the educators (45.5%) thought that *politics* and *equity & justice* were not seriously acknowledged. On the whole, about one-third of the educators (32%) perceived social concepts as either "strongly" taught or addressed "to a great extent" in engineering lectures.

Table 6.22. HEI-1 Educator perspective on curricular social content

Social Concept	$\phi_{1\text{-}2}$ (%)	ϕ_3 (%)	$\phi_{4\text{-}5}$ (%)
Bribery & corruption	40.0	23.6	36.4
Culture & religion	40.0	36.4	23.6
Demography	32.8	34.5	32.8
Diversity & cohesion	32.7	29.1	38.2
Education and training	25.4	18.2	56.4
Employment	29.1	40.0	30.9
Equity & justice	45.5	25.5	29.0
Health & safety	36.3	27.3	36.4
Labour & human right	40.0	43.6	16.4
Peace & security	27.3	40.0	32.7
Politics	45.5	32.7	21.8
Poverty	32.7	38.2	29.1
Mean	**35.6**	**32.4**	**32.0**

Note: $\phi_{1\text{-}2}$ signifies "not at all" and "slightly" responses, ϕ_3 represents "moderately", while $\phi_{4\text{-}5}$ symbolises "strongly" and "to a great extent" responses

Crosscutting Content

Opinions of HEI-1 engineering educators on the coverage of crosscutting themes in engineering lectures diverged (Table 6.23). Almost two-thirds of the educators (60%) claimed to have strongly addressed the subthemes of *communication & reporting* and *transparency in design* in their engineering lessons. With the exception of *governance* and *ethics & philosophy* subtopics, the remaining themes of the crosscutting concept were considered adequately covered in engineering lectures by a large proportion of the educators (between 45% and 57%). Averagely, over half of the HEI-1 educators (51.9%) were satisfied with the crosscutting content of the engineering courses.

Table 6.23. HEI-1 Educator perspective on curricular crosscutting content

Crosscutting Concept	ϕ_{1-2} (%)	ϕ_3 (%)	ϕ_{4-5} (%)
Comm & reporting	18.2	20.0	61.8
Ethics & philosophy	36.4	23.6	40.0
Governance	36.4	27.3	36.3
Holistic thinking	25.4	20.1	54.5
Long-term thinking	20.0	23.6	56.4
People: part of nature	25.5	29.0	45.5
Responsibility	20.0	23.6	56.4
Sustainable Dev	21.8	21.8	56.4
Systems thinking	21.8	29.1	49.1
Transparency: design	20.0	20.0	60.0
Mean	**24.6**	**23.8**	**51.6**

Note: ϕ_{1-2} signifies "not at all" and "slightly" responses, ϕ_3 represents "moderately", while ϕ_{4-5} symbolises "strongly" and "to a great extent" responses

Collation of HEI-1 Perspectives

Table 6.24 collates the perspectives of HEI-1 engineering students and educators on the sustainability content of engineering courses at the institution. The results showed that students and educators perceived the sustainability content of engineering courses somewhat differently. Whilst most educators thought that crosscutting themes featured strongly in the lectures, students largely acknowledged the environmental concepts. The economic theme was considered by the students and educators as the third and second most addressed topics respectively. Nevertheless, students and educators both agreed that social concepts were the least featured issues in engineering lectures. In terms of the combined results, a sizeable proportion of the HEI-1 stakeholders (40%) considered environmental and crosscutting themes as strongly addressed in the engineering courses. Furthermore, more than one-third of the stakeholders (37%) positively regarded the economic content of the courses. However, fewer HEI-1 engineering stakeholders (28%) perceived the engineering lessons as adequately addressing the social concepts. Interestingly, more than half of the educators (51.6%) and just over a quarter of the students (26.7%) thought the engineering lessons strongly addressed crosscutting sustainability themes. Overall, not up to one-third of the stakeholders (31.3%) had a strongly positive impression of the sustainability content of engineering courses in HEI-1.

Table 6.24. HEI-1 Stakeholder perspective on curricular sustainability content

HEI-1 Stakeholder (n=192)	Economic			Environmental			Social			Crosscutting		
	ϕ_{1-2} (%)	ϕ_3 (%)	ϕ_{4-5} (%)	ϕ_{1-2} (%)	ϕ_3 (%)	ϕ_{4-5} (%)	ϕ_{1-2} (%)	ϕ_3 (%)	ϕ_{4-5} (%)	ϕ_{1-2} (%)	ϕ_3 (%)	ϕ_{4-5} (%)
Students (n=137)	35.4	31.7	33.0	36.3	29.8	33.9	45.6	30.4	24.3	40.4	32.9	26.7
Educators (n=55)	33.9	25.2	40.9	31.9	22.6	45.4	35.6	32.4	32.0	24.6	23.8	51.6
Mean	**34.7**	**28.5**	**37.0**	**34.1**	**26.2**	**39.7**	**40.6**	**31.4**	**28.2**	**32.5**	**28.4**	**39.2**
Mean Perceived Sustainability Content ϕ_{4-5}: 31.3%												

Note: ϕ_{1-2} signifies "not at all" and "slightly" responses, ϕ_3 represents "moderately", while ϕ_{4-5} symbolises "strongly" and "to a great extent" responses

HEI-2 Student Perception (n=95)

Ninety-five HEI-2 engineering students participated in the survey on the sustainability content of engineering courses. The students' perspectives on extent of economic, environmental, social and crosscutting coverage in the engineering courses are presented in the following sections.

Economic Content

The perception of HEI-2 engineering students on the economic content of engineering lessons in their institution varied (Table 6.25). Very few students thought that economic concepts were featured "strongly" or "to a great extent" in the engineering lectures. Only a small minority of the students (12.6%) perceived the subthemes of *GNP* and *finances* as satisfactorily addressed in the lessons. However, more than half of the students (51.6%) stated that the subtopic of *accountability* was either slightly" addressed or "not at all" mentioned in engineering lectures. With a positive response average of 21.4%, HEI-2 engineering students had a generally low opinion of the economic content of engineering courses in their institution.

Table 6.25. HEI-2 Student perspective on curricular economic content

Economic Theme	$\phi_{1\text{-}2}$ (%)	ϕ_3 (%)	$\phi_{4\text{-}5}$ (%)
Accountability	51.6	29.5	18.9
Dev economics	47.3	25.3	27.4
Production patterns	43.1	26.3	30.6
Finances	47.4	40.0	12.6
Resource use	30.5	43.2	26.3
GNP	66.3	21.1	12.6
Mean	**47.7**	**30.9**	**21.4**

Note: $\phi_{1\text{-}2}$ signifies "not at all" and "slightly" responses, ϕ_3 represents "moderately", while $\phi_{4\text{-}5}$ symbolises "strongly" and "to a great extent" responses

Environmental Content

Engineering students at HEI-2 expressed divergent views on the environmental content of engineering courses (Table 6.26). Over two-fifths of them (43.2%) opined that *alternative energy* was adequately addressed in the lectures. Additionally, the subtheme of *resource depletion* was considered by a good proportion of students (39%) to be adequately discussed in engineering lessons. Fewer students thought the engineering lectures sufficiently addressed *products & services* (13.7%), *biodiversity* (15.8%), and *climate change* (27.3%). In general, the perspective of the engineering students on the coverage of environmental sustainability themes in the engineering courses was negative. Just over a quarter (28.8%) of the students felt that the courses addressed environmental issues.

Table 6.26. HEI-2 Student perspective on curricular environmental content

Environmental Theme	$\phi_{1\text{-}2}$ (%)	ϕ_3 (%)	$\phi_{4\text{-}5}$ (%)
Alternative energy	32.6	24.2	43.2
Biodiversity	47.4	36.8	15.8
Climate change	43.2	29.5	27.3
Land use	43.2	23.2	33.6
Policy & admin	42.1	32.6	25.3
Pollution	36.8	33.7	29.5
Products & services	55.8	30.5	13.7
Resource ecoefficiency	46.4	22.0	31.6
Resource depletion	29.4	31.6	39.0
Mean	**41.9**	**29.3**	**28.8**

Note: $\phi_{1\text{-}2}$ signifies "not at all" and "slightly" responses, ϕ_3 represents "moderately", while $\phi_{4\text{-}5}$ symbolises "strongly" and "to a great extent" responses

Social Content

HEI-2 engineering students expressed varying standpoints on the social content of engineering courses (Table 6.27). The majority of them (≥53%) were not impressed by the spread of several social subthemes. Only the social subtopic of *education & training* was perceived by over one-third of the students (35.8%) as featuring "strongly" or "to a great extent" in lectures. The least addressed social themes as perceived by the engineering students were *demography, bribery & corruption, culture & religion*, *politics* and *poverty.* Remarkably, almost half of the engineering students thought that *health & safety* (47.4%) and *peace & security* were either "slightly" discussed or "not at all" mentioned in the lessons. Overall, only a small minority of the engineering students (18.3%) had a high opinion of the social content of the engineering courses.

Table 6.27. HEI-2 Student perspective on curricular social content

Social Concept	**ϕ_{1-2} (%)**	**ϕ_3 (%)**	**ϕ_{4-5} (%)**
Bribery & corruption	63.2	25.3	11.5
Culture & religion	60.0	27.4	12.6
Demography	61.0	28.4	10.6
Diversity & cohesion	48.4	32.6	19.0
Education and training	33.7	30.5	35.8
Employment	49.5	30.5	20.0
Equity & justice	53.7	33.7	12.6
Health & safety	47.4	29.5	23.1
Labour & human right	54.8	30.5	14.7
Peace & security	45.3	26.3	28.4
Politics	62.1	23.2	14.7
Poverty	60.0	23.2	16.8
Mean	**53.3**	**28.4**	**18.3**

Note: ϕ_{1-2} signifies "not at all" and "slightly" responses, *ϕ_3 represents "moderately", while ϕ_{4-5} symbolises "strongly" and "to a great extent" responses*

Crosscutting Content

There was no unanimous view on the crosscutting content of engineering courses (Table 6.28). An appreciable number of the students [34%, 38%] indicated that the subtopics of *responsibility*, *communication & reporting* and *transparency in design* featured "strongly" or "to a great extent" in their lectures. Contrastingly, over half of the students (52.6%) failed to acknowledge the coverage of *holistic thinking* in the engineering lessons. On the whole, just over a quarter of the HEI-2 students (28.8%) expressed satisfaction with the crosscutting content of the engineering courses.

Table 6.28. HEI-2 Student perspective on curricular crosscutting content

Crosscutting Concept	ϕ_{1-2} (%)	ϕ_3 (%)	ϕ_{4-5} (%)
Comm & reporting	35.8	27.4	36.8
Ethics & philosophy	41.1	31.6	27.3
Governance	48.4	30.5	21.1
Holistic thinking	52.6	30.5	16.7
Long-term thinking	44.2	27.4	28.4
People: part of nature	49.5	27.4	23.1
Responsibility	34.8	31.6	33.6
Sustainable Dev	34.8	33.7	31.5
Systems thinking	35.7	36.8	27.5
Transparency: design	28.4	33.7	37.9
Mean	**40.5**	**31.1**	**28.4**

Note: ϕ_{1-2} signifies "not at all" and "slightly" responses, ϕ_3 represents "moderately", while ϕ_{4-5} symbolises "strongly" and "to a great extent" responses

HEI-2 Educator Perception (n=29)

Twenty-nine HEI-2 engineering educators responded to the curricular sustainability survey. The succeeding sections present the results of the survey based on economic, environmental, social and crosscutting themes.

Economic Content

Engineering educators at HEI-2 had varying perspectives on the economic content of engineering courses (Table 6.29). The most acknowledged economic theme was *resource use* with half of the educators (48.3%) admitting discussing the subtopic in lectures. On the other hand, *developmental economics* subtheme was considered by over half of the educators (51.7%) as featuring either slightly" or "not at all" in their teaching. Generally, a considerable number of the educators (38%) claimed to have covered economic topics in engineering lectures.

Table 6.29. HEI-2 Educator perspective on curricular economic content

Economic Theme	ϕ_{1-2} (%)	ϕ_3 (%)	ϕ_{4-5} (%)
Accountability	37.9	20.7	41.4
Dev economics	51.7	6.9	41.4
Production patterns	34.4	37.9	27.7
Finances	41.4	20.7	37.9
Resource use	31.0	20.7	48.3
GNP	44.8	24.1	31.1
Mean	**40.2**	**21.8**	**38.0**

Note: ϕ_{1-2} signifies "not at all" and "slightly" responses, ϕ_3 represents "moderately", while ϕ_{4-5} symbolises "strongly" and "to a great extent" responses

Environmental Content

The perspectives of HEI-2 engineering educators diverged on the environmental content of engineering courses (Table 6.30). Most of the educators (48.3%) indicated that the subtheme of *alternative energy* was covered in their teaching. The subtopic of *biodiversity* was, however, the least acknowledged environmental theme as barely one-fifth of the educators (20.7%) stated it was strongly addressed. Nonetheless, over one-third of the HEI-2 educators (36.8%) largely agreed that environmental concepts were intensely treated in engineering lessons.

Table 6.30. HEI-2 Educator perspective on curricular environmental content

Environmental Theme	$\phi_{1\text{-}2}$ (%)	ϕ_3 (%)	$\phi_{4\text{-}5}$ (%)
Alternative energy	31.0	20.7	48.3
Biodiversity	34.5	44.8	20.7
Climate change	24.1	34.5	41.3
Land use	44.8	24.1	31.1
Policy & admin	44.8	17.2	38.0
Pollution	37.9	17.2	44.8
Products & services	44.8	24.1	31.1
Resource ecoefficiency	31.0	31.0	38.0
Resource depletion	27.5	34.5	38.0
Mean	**35.6**	**27.6**	**36.8**

Note: $\phi_{1\text{-}2}$ *signifies "not at all" and "slightly" responses*, ϕ_3 *represents "moderately", while* $\phi_{4\text{-}5}$ *symbolises "strongly" and "to a great extent" responses*

Social Content

Opinions of HEI-2 educators varied on the social content of engineering courses (Table 6.31). Only *education & training* and *labour & human right* were considered as adequately stressed in engineering lessons by two-fifths of the educators (40%). Just over one-third of the educators (34%) had a strongly positive opinion about treating *bribery & corruption*, *diversity & cohesion*, and *equity & justice* in engineering lectures. Interestingly, more than half of the educators agreed to have "slightly" highlighted issues of *culture & religion* in lectures. Overall, less than one-third of the educators (31%) admitted teaching social topics "to a great extent" or "strongly" during lessons.

Table 6.31. HEI-2 Educator perspective on curricular social content

Social Concept	$\phi_{1\text{-}2}$ (%)	ϕ_3 (%)	$\phi_{4\text{-}5}$ (%)
Bribery & corruption	34.5	31.0	34.5
Culture & religion	51.7	24.1	24.2
Demography	44.8	27.6	27.6
Diversity & cohesion	51.7	13.8	34.5
Education and training	31.0	27.6	41.4
Employment	34.5	27.6	37.9
Equity & justice	37.9	27.6	34.5
Health & safety	34.4	34.5	31.1
Labour & human right	44.8	17.2	38.0
Peace & security	41.3	27.6	31.1
Politics	44.8	37.9	17.3
Poverty	37.9	37.9	24.2
Mean	**40.8**	**27.9**	**31.4**

Note: $\phi_{1\text{-}2}$ signifies "not at all" and "slightly" responses, ϕ_3 represents "moderately", while $\phi_{4\text{-}5}$ symbolises "strongly" and "to a great extent" responses

Crosscutting Content

The treatment of crosscutting concepts in engineering lectures was viewed variously by HEI-2 engineering educators (Table 6.32). The majority of the educators (≥55%) admitted featuring the subthemes of *governance*, *responsibility*, and *transparency in design* "strongly" or "to a great extent" in lectures. About half of the educators (48.4%) claimed to have addressed the subtopics of *systems thinking* and *communication & reporting.* Nonetheless, *long-term thinking* was thought to have featured "slightly" or "not at all" in engineering lessons by over two-fifths of the educators (41.3%). On average, nearly half of the educators (47%) regarded the coverage of crosscutting concepts in engineering lessons as highly accomplished.

Table 6.32. HEI-2 Educator perspective on curricular crosscutting content

Crosscutting Concept	$\phi_{1\text{-}2}$ (%)	ϕ_3 (%)	$\phi_{4\text{-}5}$ (%)
Comm & reporting	20.6	31.0	48.4
Ethics & philosophy	31.0	31.0	38.0
Governance	31.0	13.8	55.2
Holistic thinking	34.5	31.0	34.5
Long-term thinking	41.3	17.4	41.3
People: part of nature	34.5	20.7	44.8
Responsibility	27.5	17.2	55.3
Sustainable Dev	24.1	31.0	44.9
Systems thinking	34.4	17.2	48.4
Transparency: design	31.0	10.3	58.7
Mean	**31.0**	**22.1**	**47.0**

Note: $\phi_{1\text{-}2}$ signifies "not at all" and "slightly" responses, ϕ_3 represents "moderately", while $\phi_{4\text{-}5}$ symbolises "strongly" and "to a great extent" responses

Collation of HEI-2 Perspectives

The perspectives of HEI-2 engineering stakeholders on the sustainability content of engineering courses are collated in Table 6.33. Stakeholders expressed a difference of opinion on the sustainability content of engineering lessons. More educators than students considered crosscutting themes as covered "strongly" or "to a great extent" in lectures. The students were of the view that environmental topics received the most attention. Perspectives of educators and students on the economic theme split into second and third most featured topic respectively. Social topic was commonly seen as least highlighted in engineering lessons. However, considering the mean percentages, over one-third of stakeholders (37.7%) thought highly of the crosscutting content. About one-third (32.8%) viewed environmental theme as strongly cited in lectures, whilst barely 30% perceived economic theme likewise. Only a quarter of the stakeholders (24.9%) were content by the mention of social topics. Largely, over a third of the stakeholders (36%) acclaimed the sustainability content of HEI-2 engineering courses.

Table 6.33 HEI-2 Stakeholder perspective on curricular sustainability content

HEI-2 Stakeholder (n=124)	Economic			Environmental			Social			Crosscutting		
	ϕ_{1-2} (%)	ϕ_3 (%)	ϕ_{4-5} (%)	ϕ_{1-2} (%)	ϕ_3 (%)	ϕ_{4-5} (%)	ϕ_{1-2} (%)	ϕ_3 (%)	ϕ_{4-5} (%)	ϕ_{1-2} (%)	ϕ_3 (%)	ϕ_{4-5} (%)
Students (n=95)	47.7	30.9	21.4	41.9	29.3	28.8	53.3	28.4	18.3	40.5	31.1	28.4
Educators (n=29)	40.2	21.8	38.0	35.6	27.6	36.8	40.8	27.9	31.4	31.0	22.1	47.0
Mean	**44.0**	**26.4**	**29.7**	**38.8**	**28.5**	**32.8**	**47.1**	**28.2**	**24.9**	**35.8**	**26.6**	**37.7**

Mean Perceived Sustainability Content ϕ_{4-5}: 36.0%

Note: ϕ_{1-2} signifies "not at all" and "slightly" responses, ϕ_3 represents "moderately", while ϕ_{4-5} symbolises "strongly" and "to a great extent" responses

Result Synthesis

Documentary Sustainability Content

Table 6.34 and Table 6.35 summarise the results of the content analyses. Mentions of sustainability themes differed in emphasis from one theme to another across the documents. In the BMAS document, for example, economic theme had the highest percentage coverage, which differed from HEI-1 and HEI-2 engineering handbooks that emphasised environmental and crosscutting topics respectively. Social theme received second lowest coverage in both HEI-1 and HEI-2 engineering handbooks, and worst coverage in the BMAS document. Crosscutting and economic themes were the worst covered sustainability topics in HEI-1 and HEI-2 engineering handbooks respectively. Largely, sustainability themes were featured mainly in non-core courses such as engineering management. Only the BMAS document explicitly mentioned sustainability competence as a learning outcome for an engineering graduate. Overall, the sustainability content of the programmes based on the documentary analysis was low at a mean spread of 4.3% (13.37% average potential content).

Table 6.34. Sustainability content by Nigerian engineering programmes

Engineering Programme	Frequencies				Sustainability ∑(frequencies)
	Economic	Environmental	Social	Crosscutting	
Aerospace Engineering	0	0	0	3	**3**
Agricultural Engineering	1	2	0	0	**3**
Automotive Engineering	0	0	0	0	**0**
Biomedical Engineering	1	0	0	0	**1**
Ceramic Engineering	0	0	0	0	**0**
Chemical Engineering	2	2	1	0	**5**
Civil Engineering	2	3	1	2	**8**
Common Courses	1	1	1	4	**7**
Communications Engineering	1	0	1	1	**3**
Computer Engineering	0	0	1	1	**2**
Electrical & Electronic Engineering	0	0	0	0	**0**
Environmental Engineering	0	4	1	0	**5**
Food Engineering	0	0	0	0	**0**
Gas Engineering	2	0	0	0	**2**
Industrial & Production Engineering	2	0	0	0	**2**
Industrial Engineering	0	0	1	0	**1**
Marine Engineering	0	0	0	0	**0**
Mechanical Engineering	2	1	0	1	**4**
Mechatronics Engineering	1	1	0	2	**4**
Metallurgical & Materials Engineering	2	1	1	2	**6**
Mining Engineering	2	1	3	2	**8**
Petrochemical Engineering	0	1	0	0	**1**
Petroleum Engineering	2	1	0	0	**3**
Production Engineering	0	0	1	0	**1**
Public Health Engineering	0	1	1	0	**2**
Refrigeration & Air Conditioning	0	0	0	0	**0**
Structural Engineering	0	0	0	0	**0**
Systems Engineering	0	2	0	0	**2**
Textile & Polymer Engineering	0	0	0	0	**0**
Water Resources Engineering	0	2	1	1	**4**
Wood Products Engineering	1	1	1	0	**3**
Total	22	24	15	19	**80**

Table 6.35. Summary of documentary sustainability content

Document	Economic % coverage	Environmental % coverage	Social % coverage	Crosscutting % coverage	Sustainability % coverage
BMAS	0.65 (15.59)*	0.57 (7.53)*	0.45 (2.96)*	0.48 (6.13)*	2.15 (8.05)*
HEI-1 EngHandbook	1.60 (18.33)*	3.55 (31.11)*	1.13 (5.00)*	0.85 (15.00)*	7.13 (17.36)*
HEI-2 EngHandbook	0.60 (12.50)*	1.06 (13.88)*	0.66 (12.50)*	1.33 (20.00)*	3.65 (14.72)*
Mean	**1.0 (15.47)**	**1.7 (17.48)**	**0.7 (6.82)**	**0.9 (13.71)**	**4.3 (13.37)**

*Note: * figure in parenthesis represents percentage within theme's potential content or coverage*

Perceived Sustainability Content

Perspectives of HEI-1 and HEI-2 engineering community are collated in Table 6.36. With the exception of crosscutting and environmental themes, there was an almost one-to-one match in the stakeholders' perspectives on the coverage of sustainability themes in engineering courses. The difference manifested in the consideration of environmental theme by HEI-1 engineering community as having received the most attention in the courses. HEI-2 engineering stakeholders, by contrast, thought it was the crosscutting theme. Both groups of stakeholders, however, agreed that the social theme was the least mentioned sustainability topic in engineering lessons, followed by the economic theme. Based on the mean percentages of the themes, almost two-fifths of the stakeholders [36.3%, 38.5%] viewed environmental and crosscutting topics as addressed "strongly" or "to a great extent" in engineering teaching. Economic theme was perceived as featuring "strongly" or "to a great extent" in the lectures by one-third of the stakeholders (33.4%). Just over a quarter of the stakeholders (26.6%) thought social topics were adequately addressed in engineering lectures. On the whole, one-third of the stakeholders (33.7%) regarded sustainability topics as contained "strongly" or "to a great extent" in engineering curriculum.

Table 6.36. Summary of stakeholder perceived sustainability content

Stakeholder (n=316)	Economic			Environmental			Social			Crosscutting		
	ϕ_{1-2} (%)	ϕ_{3} (%)	ϕ_{4-5} (%)	ϕ_{1-2} (%)	ϕ_{3} (%)	ϕ_{4-5} (%)	ϕ_{1-2} (%)	ϕ_{3} (%)	ϕ_{4-5} (%)	ϕ_{1-2} (%)	ϕ_{3} (%)	ϕ_{4-5} (%)
HEI-1 (n=192)	**34.7**	**28.5**	**37.0**	**34.1**	**26.2**	**39.7**	**40.6**	**31.4**	**28.2**	**32.5**	**28.4**	**39.2**
HEI-2 (n=124)	**44.0**	**26.4**	**29.7**	**38.8**	**28.5**	**32.8**	**47.1**	**28.2**	**24.9**	**35.8**	**26.6**	**37.7**
Mean	**39.4**	**27.5**	**33.4**	**36.5**	**27.4**	**36.3**	**43.9**	**29.8**	**26.6**	**34.2**	**27.5**	**38.5**

Mean Perceived Sustainability Content ϕ_{4-5}: 33.7%

Note: ϕ_{1-2} *signifies "not at all" and "slightly" responses*, ϕ_{3} *represents "moderately", while* ϕ_{4-5} *symbolises "strongly" and "to a great extent" responses*

Harmonised Sustainability Content

Table 6.37 summarises the result of sustainability content analysis of engineering documents and stakeholders' perspectives. With a mere 13.37% average potential documentary coverage and 33.7% ϕ_{4-5} mean perceived content, the sustainability content of the Nigerian engineering curriculum was largely unsatisfactory. Evidently, a significant majority of the stakeholders agreed on the poor content of sustainability themes in engineering studies. Nonetheless, for comparative purposes a ranking of the sustainability themes based on the percentage of sustainability content was derived from the documentary and perceptive analyses. The documentary analysis showed that environmental themes had, on average, the most coverage followed in turn by economic, crosscutting and social concepts. In terms of the mean perceived content, on the other hand, the crosscutting topics ranked highest trailed by the environmental, economic, and social themes respectively.

Table 6.37. Content-wise ranking of sustainability themes

Ranking	1st	2nd	3rd	4th	Mean Sustainability Content (%)
Documentary Content	Environmental	Economic	Crosscutting	Social	13.37
Perceived Content	Crosscutting	Environmental	Economic	Social	33.7

In Table 6.38 a harmonised ranking of the sustainability themes is presented. From the results, sustainability concepts dispersed within the engineering curriculum with more environmental themes than crosscutting concepts. Similarly, crosscutting issues appeared in the curriculum more than economic themes. Lastly, the curriculum contained less social topics than economic concepts.

Table 6.38. Harmonised ranking of sustainability themes

Theme	Documentary Content Points	Perceived Content Points	Total Points	Ranking
Environmental	4	3	7	1st
Crosscutting	2	4	6	2nd
Economic	3	2	5	3rd
Social	1	1	2	4th

Sustainability Content of UCL Engineering Curriculum

Although there is no explicit reference to sustainability as an objective of the UCL IEP, it will be interesting to evaluate the spread of sustainability themes in the UCL engineering curriculum. Given that the UCL IEP model is considered world leading in engineering education (Graham, 2018), a comparison of its sustainability content with that of the Nigerian engineering curriculum could be illuminating. In the following sections, the results of an assessment of the sustainability content of the UCL engineering curriculum are presented.

Economic Content

Economic concepts were featured unevenly in the UCL engineering curriculum (Figure 6.13 and Table 6.39). *GNP* did not appear in any of the engineering programmes. The most frequent subtheme was *finances*, which was cited 12 times in the UCL IEP minors and four times in UCL Biochemical Engineering. The subtopic of *developmental economics* was mentioned at least once in all the core engineering courses. There was a slight mention of economic concepts in the core disciplines of UCL Electronic and Electrical and UCL Mechanical Engineering. Generally, economic concepts had a reasonable presence in the UCL IEP minors. However, the UCL engineering curriculum had a modest economic content with about 3% of the curriculum featuring economic topics.

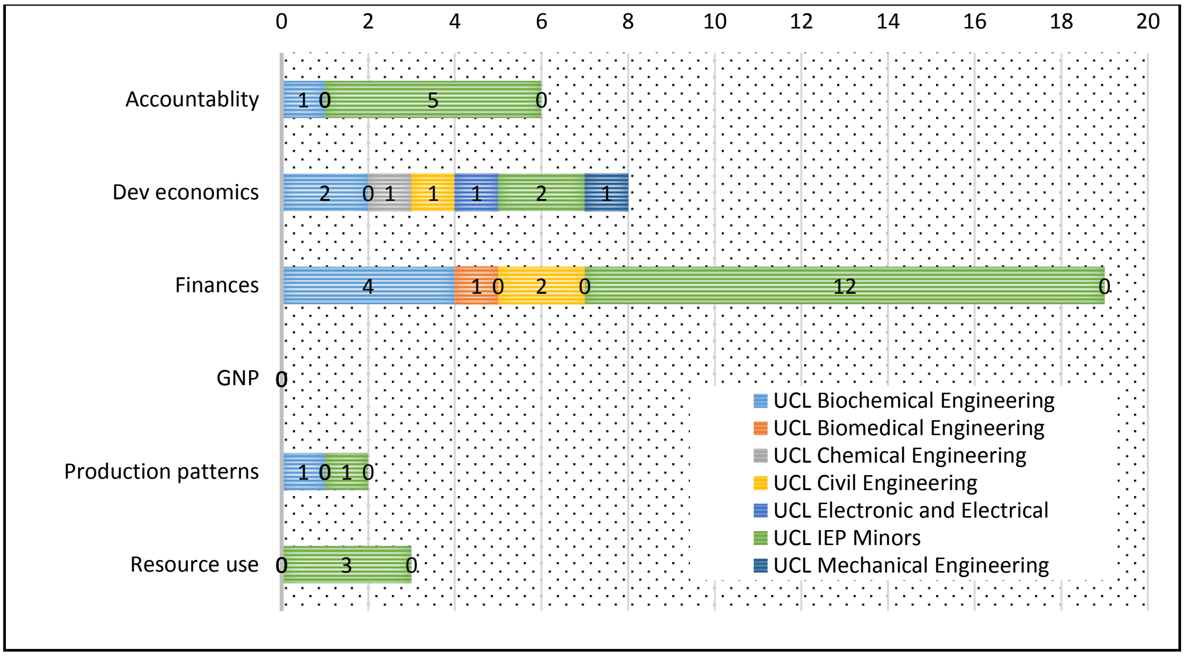


Figure 6.13. Economic content of UCL engineering curriculum

Table 6.39. Descriptive statistics of UCL engineering economic content

Engineering Programme	Frequency	% within programme**
UCL Biochemical Engineering	8	0.63
UCL Biomedical Engineering	1	0.02
UCL Chemical Engineering	1	0.37
UCL Civil Engineering	3	0.08
UCL Electronic and Electrical	1	0.15
UCL Mechanical Engineering	1	0.03
UCL IEP Minors	23	1.43
Economic content	38	2.71

*** Obtained directly from NVivo calculations as average of characters and page area percentages*

Environmental Content

The presence of environmental concepts in the UCL engineering curriculum varied (Figure 6.14 and Table 6.40). The most cited environmental subtopic was *policy & admin*, appearing 18 times in the engineering programmes. The subtheme of *climate change* only featured in the UCL IEP minors. *Pollution* was mentioned in all the engineering programmes except UCL Electronic and Electrical Engineering. With the exception of *land use*, the UCL IEP minors featured all the environmental subthemes at least thrice. Overall, environmental concepts appeared 38 times in the UCL IEP minors and 78 times in the entire engineering curriculum. Hence, UCL engineering curriculum had a considerable environmental content with around 13% of the curriculum covering the environmental themes.

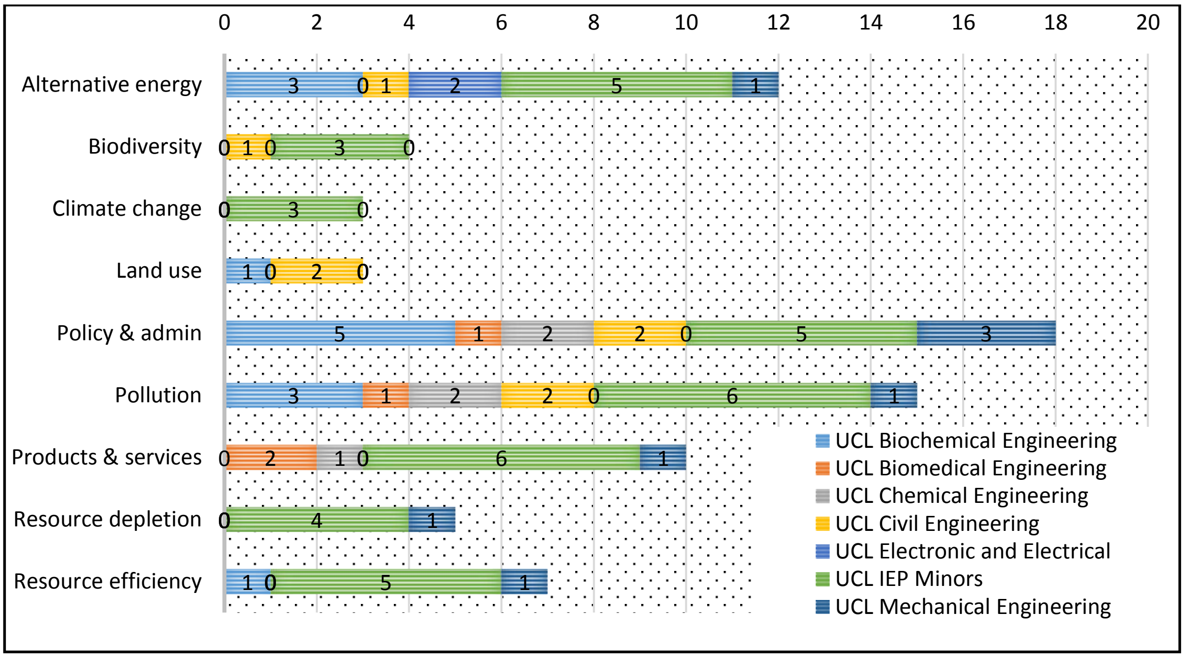


Figure 6.14. Environmental content of UCL engineering curriculum

Table 6.40. Descriptive statistics of UCL engineering environmental content

Engineering Programme	Frequency	% within programme**
UCL Biochemical Engineering	13	1.24
UCL Biomedical Engineering	4	0.17
UCL Chemical Engineering	5	1.19
UCL Civil Engineering	8	5.48
UCL Electronic and Electrical	2	1.95
UCL Mechanical Engineering	8	0.59
UCL IEP Minors	38	2.20
Environmental content	78	12.82

*** Obtained directly from NVivo calculations as average of characters and page area percentages*

Social Content

Social concepts were spread sparingly in the UCL engineering curriculum (Figure 6.15 and Table 6.41). The four social subthemes of *bribery & corruption*, *diversity & cohesion*, *education & training*, and *poverty* were absent in the engineering curriculum. The most frequent social theme was *health & safety*, which occurred 21 times in the engineering programmes. Five of the 12 social concepts featured in the UCL IEP minors. The UCL Electronic and Electrical Engineering was bereft of any social topic in its core courses. Generally, the social themes appeared 45 times in the UCL engineering curriculum, though nearly half of the mentions was in the UCL IEP minors. Thus, the social content of the UCL engineering curriculum was not widespread having recorded about 2% coverage.

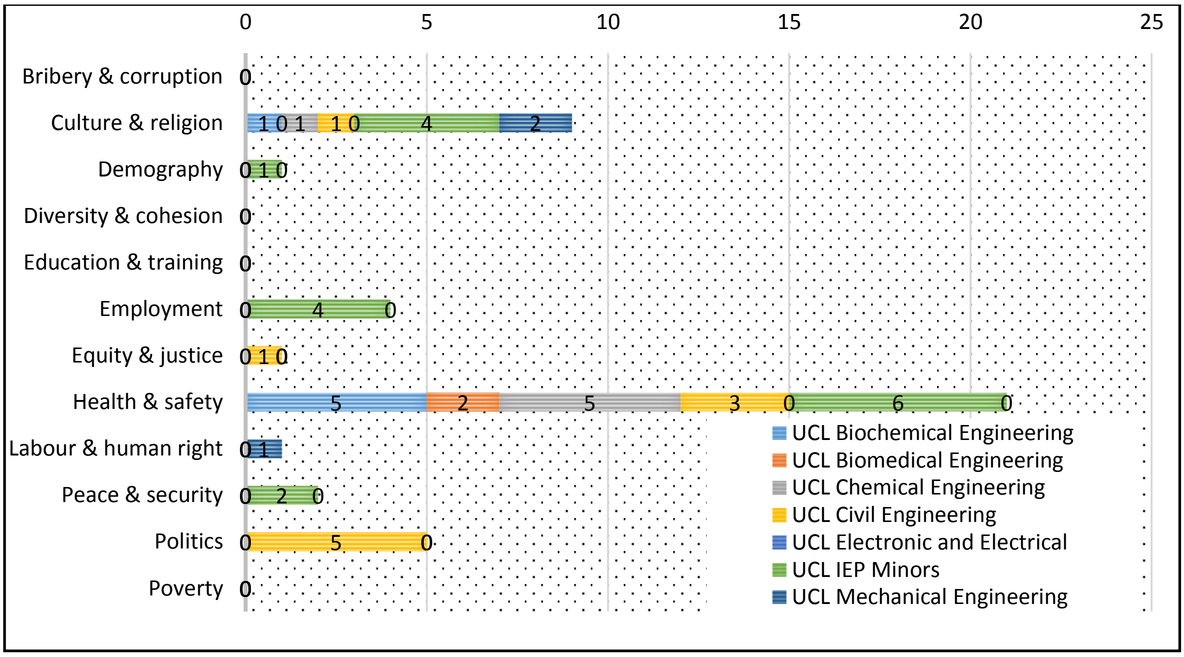


Figure 6.15. Social content of UCL engineering curriculum

Table 6.41. Descriptive statistics of UCL engineering social content

Engineering Programme	Frequency	% within programme**
UCL Biochemical Engineering	6	0.42
UCL Biomedical Engineering	2	0.20
UCL Chemical Engineering	6	0.85
UCL Civil Engineering	10	0.45
UCL Electronic and Electrical	0	0.00
UCL Mechanical Engineering	3	0.25
UCL IEP Minors	18	1.54
Social content	45	3.71

*** Obtained directly from NVivo calculations as average of characters and page area percentages*

Crosscutting Content

The coverage of crosscutting concepts in the UCL engineering curriculum is shown in Figure 6.16 and Table 6.42. All the 10 crosscutting subthemes appeared at least once in the engineering curriculum. Each of the themes was mentioned at least once in the UCL IEP minors. Featuring in all the programmes, *communication & reporting* was the most recurring crosscutting topic. *Sustainable development* was also mentioned in all the programmes. The least cited crosscutting concept was *people as part of nature* as it occurred once each in UCL Electronic and Electrical and UCL IEP minors. UCL Civil Engineering and UCL Chemical Engineering had a significant coverage of crosscutting concepts. Crosscutting themes generally appeared 129 times in the UCL engineering curriculum. With more than one-fifth (~22%) of the curriculum devoted to these concepts, the engineering curriculum at UCL had a remarkable crosscutting content.

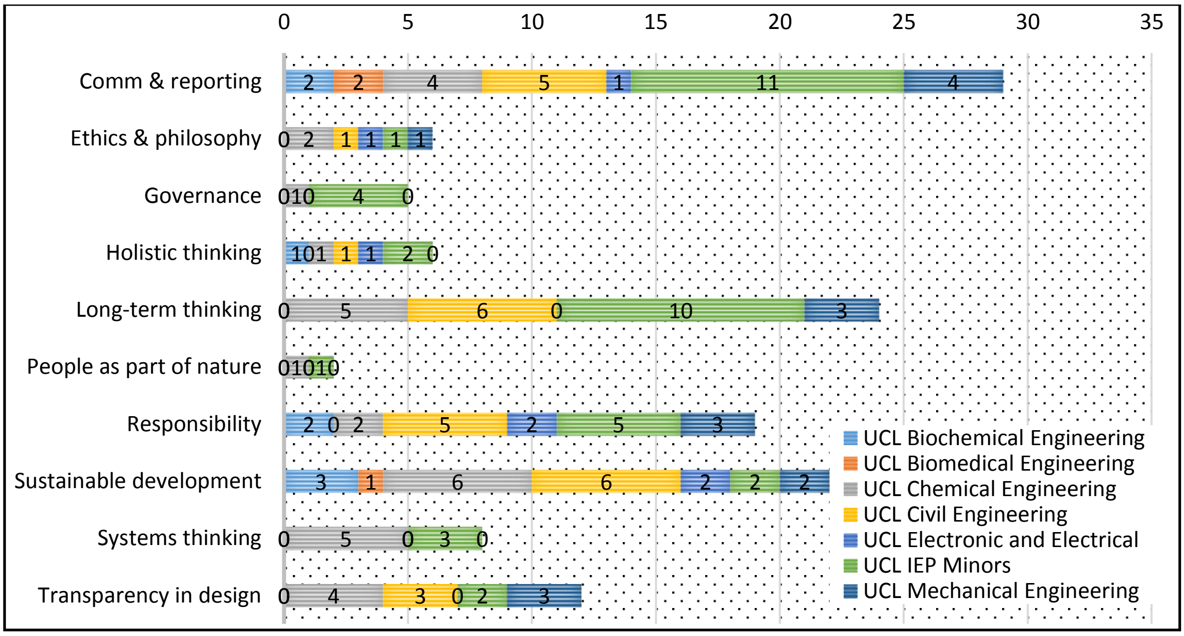


Figure 6.16. Crosscutting content of UCL engineering curriculum

Table 6.42.Descriptive statistics of UCL engineering crosscutting content

Engineering Programme	Frequency	% within programme**
UCL Biochemical Engineering	8	1.13
UCL Biomedical Engineering	3	0.13
UCL Chemical Engineering	28	10.51
UCL Civil Engineering	27	3.24
UCL Electronic and Electrical	6	1.58
UCL Mechanical Engineering	16	2.62
UCL IEP Minors	41	2.74
Crosscutting content	129	21.95

*** Obtained directly from NVivo calculations as average of characters and page area percentages*

Summary of UCL Engineering Sustainability Content

The sustainability content of the UCL engineering curriculum can be approximated from a collation of the sustainability themes as presented in Table 6.43. A summation of the frequencies and percentages of the themes shows that sustainability concepts appeared 290 times in the UCL engineering curriculum, corresponding to a 42% of the engineering syllabuses. The most frequently mentioned sustainability themes were the crosscutting concepts followed by the environmental, social and economic concepts respectively. The UCL IEP minors had the highest coverage of sustainability topics which appeared 120 times in the interdisciplinary courses. Trailing the UCL IEP minors in terms of sustainability coverage were the UCL Civil Engineering and UCL Chemical Engineering, with sustainability themes occurring 48 and 40 times respectively. With only nine mentions of sustainability themes in its core courses, the UCL Electronic and Electrical Engineering had the lowest sustainability content.

Table 6.43. Summary of UCL engineering sustainability content

Engineering Programme	Frequencies				Sustainability
	Economic	Environmental	Social	Crosscutting	∑(frequencies)
UCL Biochemical Engineering	8	13	6	8	35
UCL Biomedical Engineering	1	4	2	3	10
UCL Chemical Engineering	1	5	6	28	40
UCL Civil Engineering	3	8	10	27	48
UCL Electronic and Electrical	1	2	0	6	9
UCL Mechanical Engineering	1	8	3	16	28
UCL IEP Minors	23	38	18	41	120
Total	**38**	**78**	**45**	**129**	**290**
Percentage covered**	**3%**	**13%**	**4%**	**22%**	**42%**

*** Obtained directly from NVivo calculations as average of characters and page area percentages*

Discussion

Sustainability Content of BMAS and Engineering Handbooks

Being the official benchmark for engineering programmes in Nigeria, BMAS guides the development of engineering curriculum in Nigerian HEIs. Assessing the BMAS for sustainability content is therefore crucial to providing a baseline on the coverage of sustainability concepts in Nigerian engineering education. Following on from such assessment could be analysis of actual engineering handbooks operationalised in the HEIs. In this study, HEI-1 and HEI-2 engineering handbooks have been assessed for sustainability content alongside the BMAS document. Whilst the BMAS features 30 engineering programmes, HEI-1 and HEI-2 engineering handbooks contain nine and three engineering courses respectively. Averagely, all three documents have shown low sustainability content based on the potential sustainability coverage of the documents and programmes.

Studies on sustainability content of engineering curricula in African higher education are scant as sustainability is an emerging interest on the continent (UNESCO, 2014). However, inadequate sustainability coverage has been reported in some of the few studies that have been undertaken. In a generic sustainability study of 69 African institutions barely a quarter of the surveyed HEIs (25%) admitted to have integrated sustainability themes in their various programmes (GUNi *et al*., 2011). Similar finding is reported in a content analysis of a management course in a Ghanaian polytechnic (Etse and Ingley, 2016). Outside the African continent in regions with relatively visible sustainability education, studies have generally revealed insufficient sustainability coverage, especially in engineering programmes (Lozano and Watson, 2013; Watson, *et al*., 2013). Hence, sustainability education efforts need to be sustained at every stage of intervention.

In the present study sustainability themes are not distributed equally in the engineering documents. BMAS, for instance, contains more economic themes than it mentions environmental, crosscutting and social concepts respectively. Conversely, HEI-1 engineering handbook covers more environmental issues than economic, crosscutting and social themes respectively. In HEI-2 engineering handbook, crosscutting themes feature more than environmental, social and economic concepts. This finding suggests that there is no one-to-one match between BMAS sustainability content and sustainability content of the engineering handbooks. A possible explanation for this discrepancy could be the lack of a focused sustainability education agenda in the BMAS document. Excepting the nonspecific learning outcome that an engineering graduate must have the ability "*to consider the environment and sustainability in finding solutions to problems*" (BMAS, 2014, p.20), the benchmark document has no explicit sustainability strategy. Such inexplicit expectation, which is absent in the engineering handbooks, coupled with the failure to feature sustainability issues as programme requirements might have contributed to the mismatch between the BMAS and the engineering handbooks. Thus, to preclude the arbitrary coverage of sustainability themes in engineering education a sustainability education intervention must be precise, contextual and integrative.

Stakeholder Perspectives and Engineering Handbooks

Student and educator perspectives on sustainability content of engineering curriculum are important in a sustainability education research of this nature. These data could provide useful insight into the effectiveness of engineering curriculum in conveying sustainability themes. In addition, the information may either corroborate or contradict the emerging perspectives within individual cohorts as well as affirm or disaffirm results of the content analysis. Findings of the present study reveal a difference of opinion between educators and students on the sustainability content of engineering courses. The study also uncovers an instance of dissonance between stakeholders' perspectives and documentary sustainability content.

From the perspective of HEI-1 educators, sustainability themes sorted by percentage coverage begin with crosscutting themes followed by environmental, economic and social topics respectively. On the contrary, environmental topics feature before economic, crosscutting and social topics based on HEI-1 students' perspectives. Interestingly, results of the documentary analysis of HEI-1 engineering handbook tally with the students' perspectives. For HEI-2 stakeholders, educators perceive crosscutting themes to be the most covered followed by economic, environmental, and social topics, whilst students stress environmental themes before crosscutting, economic, and social topics respectively. HEI-2 engineering handbook does not wholly reflect either perspectives except for social themes – decidedly the least cited in all instances.

With respect to the dissonance between perspectives of students and educators, studies have commonly reported a difference in perception of education amongst stakeholders (Ezen, 2014; Könings *et al.*, 2014). Educators and students tend to perceive learning environments differently, attributable to a number of factors including teaching and learning approaches (Könings *et al.*, 2014). The educators in this study might have covered certain aspects of sustainability which could have escaped the students, thereby leading to conflicting views. Also, since educators are normally restricted to teaching a specific course, it is likely that their perceptions of sustainability content will be relative to an assigned course of instruction. Naturally, such perspective will differ from that of the students who are beneficiaries of the whole programme.

Students' familiarity with curricular content could account for the one-to-one match between HEI-1 students' perspectives and sustainability content of the engineering handbook. However, such outcome is not replicated with HEI-2 students, which indicates a gap between the HEI-2 stakeholders and documentary sustainability content. Mismatch between learners' perception and course content has been attributed to an improperly designed curriculum amongst other causes (Stefani, 2015). Hence, the conflicting results of the HEI-2 sustainability assessment could be explained by a lack of an effective sustainability education curriculum. Generally, the dearth of a focused sustainability integration in the engineering curriculum could be adduced for the differing sustainability assessment results in the study.

Harmonised Curricular Sustainability Content

From the synthesised result of the present research, the Nigerian engineering curriculum has a perceived low sustainability content and social sustainability is the least addressed theme. However, the outcome of the harmonised results does not differ significantly from the findings of several sustainability studies. For instance, early sustainability studies on engineering curriculum have reported a low sustainability content, especially in pre-intervention situations (Azapagic *et al*., 2005; EESD-Observatory, 2006). Where intervention has occurred, studies have shown that environmental topics are usually the dominant sustainability themes with social topics being poorly cited (Byrne *et al.*, 2010a). Hence the findings of the present research agree with numerous sustainability studies. An intervention is, therefore, necessary to align the Nigerian engineering education with sustainability ideals focusing on a balance amongst the sustainability themes.

The low sustainability content of the Nigerian engineering curriculum is not an unexpected outcome as no decisive steps have been taken in Nigeria to embed sustainability into engineering education. Indeed, the current research was driven by the realisation that Nigeria has no extant sustainability education model (see *Chapter Three*). The sparse sustainability concepts found in the Nigerian engineering curriculum have come mainly from management and ethics courses – conventional units in engineering programmes (Holm *et al*., 2014). These standard modules are not purpose-designed for sustainability and therefore lack the necessary sustainability finesse. However, since the courses already feature some sustainability themes, sustainability education could subsume them as part of an effective intervention for the Nigerian engineering curriculum. This would provide an opportunity for bridging the gap in the sustainability content of the curriculum.

UCL Engineering Sustainability Content

The UCL engineering curriculum has been shown to have a considerable sustainability presence. However, the bulk of the sustainability content is traceable to the UCL IEP minors. Intrinsically, the core engineering disciplines are typified by low sustainability presence, as in the case of the UCL Electronic and Electrical Engineering which has only nine mentions of sustainability, and modest sustainability content, as in the UCL Civil Engineering where sustainability themes appear 48 times. It is noteworthy that the design and professional skills module accounts for a great deal of the sustainability presence in the core disciplines. In addition, the distribution of sustainability themes across the UCL IEP minors is not even. Whilst a few of the UCL IEP minors make no reference to sustainability issues, most of them cite numerous sustainability themes. Nonetheless, the social aspects of sustainability are generally the least frequent topics in the UCL IEP minors.

The implication of the unbalanced coverage of sustainability across the UCL IEP minors is the possibility of students choosing only the modules with low sustainability content. Given that a student is required to select a set of three UCL IEP minors, it is conceivable that the minors chosen might not provide the student with a satisfactory sustainability knowledge. Although the design and professional skills module that is interwoven with the core engineering disciplines contains some sustainability themes, the sustainability content of the course unit is not independently adequate. Thus, it is not a given that the UCL engineering curriculum, despite its remarkable sustainability content, guarantees a laudable sustainability literacy. Nevertheless, the high presence of sustainability themes in the engineering curriculum might increase the chances of sustainability awareness amongst the UCL engineering students.

UCL and Nigerian Engineering Sustainability Contents

The analysis of the sustainability content of the UCL engineering curriculum reveals a path to sustainability in engineering education, i.e. through the UCL IEP framework. However, this means of sustainability integration has been shown to have both merits and demerits, which supports the view that there is no one universally effective way of incorporating sustainability in engineering education (Jowitt, 2004; UNESCO, 2005c; Manteaw, 2012). To explore this point further, the UCL engineering curriculum is contrasted with the Nigerian engineering curriculum, both of which stress the value of sustainability in engineering education. Table 6.44 shows the number of occurrences of four sustainability themes in the two curricula. The sum of the frequencies in the last column of the table is the measure of the sustainability content of each curriculum.

Starting with the economic content, the UCL engineering curriculum has almost twice as many mentions of economic concepts as the Nigerian engineering curriculum. The environmental mentions in the Nigerian engineering curriculum are one-third of the environmental concepts featured in the UCL engineering curriculum. Additionally, the social themes of sustainability are mentioned in the UCL engineering curriculum three times more than they featured in the Nigerian engineering curriculum. The frequency of the crosscutting concepts in the UCL engineering curriculum is seven times higher than that of the Nigerian engineering curriculum. On the whole, whilst sustainability themes are mentioned 290 times in the UCL engineering curriculum, they featured 80 times in the Nigerian engineering curriculum.

Table 6.44. Comparison of UCL and Nigerian engineering sustainability contents

Engineering Programme	Frequencies				Sustainability
	Economic	Environmental	Social	Crosscutting	$\sum$(frequencies)
UCL Engineering Curriculum	38	78	45	129	290
Nigerian Engineering Curriculum	22	24	15	19	80

The dissimilarities between the UCL and the Nigerian engineering curricula raise some pertinent questions. For example, do the core disciplines in the UCL engineering curriculum have more sustainability content than those of the Nigerian engineering curriculum? Another worthy question is whether the UCL engineering students, by virtue of the UCL engineering curriculum, are more sustainability literate than their counterparts in Nigeria. With regard to the latter enquiry, there is no definitive answer as the present study did not assess the sustainability literacy of the UCL engineering students. However, based on the preceding observation that the UCL engineering sustainability content is mainly in the optional UCL IEP minors, the sustainability awareness of the two sets of students might not differ significantly. As regards the former question, it is evident from the findings (Table 7.34 and Table 7.43) that the core engineering disciplines of both UCL and Nigerian engineering curricula do not differ markedly in terms of sustainability content. The only exception is with the crosscutting content in which UCL Civil Engineering and UCL Chemical Engineering trump the Nigerian equivalents.

The poor presence of sustainability in the core disciplines of the UCL and the Nigerian engineering curricula underscores the difficulty of suffusing specialised fields with sustainability topics. This fact has been copiously reported in the literature which adduce the packed nature of the engineering curriculum as a contributing factor (Allenby, 2007; Sherren, 2007; Sivapalan, 2015). Acknowledging this challenge, Jowitt (2004, p.86) maintains that rather than “shoving more material into an already overcrowded curriculum“, a focus on the learning process and the systems perspective will be an effective strategy of sustainability inclusion in engineering education. The UCL IEP framework exemplifies such recalibration of the engineering learning process that has yielded some sustainability content. However, since it is not informed by an explicit sustainability worldview, it can only go so far as evidenced in the present study. The implication for the Nigerian engineering curriculum is the need to combine proportionately content and process to attain an optimum level of sustainability content that will guarantee sustainability literacy amongst Nigerian engineering graduates.

Limitations

The sustainability assessment approach adopted in the study is constrained by the problem of defining sustainability content – the question of what constitutes a sustainability syllabus. Consequently, how to measure the sustainability content of a pedagogical document is not unambiguous. Expert-derived sustainability themes as employed in this study are a useful means of gauging sustainability content. However, the resulting sustainability topics are equivocal and the derived catalogue unavoidably incomplete. No expert listing of sustainability themes can be exhaustive enough to cover all aspects of sustainability, which is underlain by the fluidity of the sustainability concept. These inherent constraints may have limited the research's potential for a comprehensive appraisal of the sustainability content of the Nigerian engineering curriculum. Topics in the engineering documents that could qualify as sustainability content might have been overlooked for not fitting the *a priori* codes derived from the sustainability themes.

Being derivatives of the well-established pillars of sustainability, the codes have been used effectively in similar studies around the world (Segalas *et al.*, 2010; Lozano and Watson, 2013; Watson *et al.*, 2013; de Pauw *et al.*, 2014). These investigations are, nonetheless, in post-intervention contexts in which oversight of a potentially qualified sustainability idea is more likely than in a pre-intervention context, such as the present study. The post-intervention context could contain certain sustainability ideas that may not necessarily align with the expert-derived themes, whereas the pre-intervention state may be completely bereft of sustainability topics. Therefore, any sustainability-related ideas or topics in the pre-intervention contexts will be reasonably conspicuous. Consequently, the *a priori* codes were suitable for the baseline sustainability content assessment undertaken in the present study, and also appropriate for appraising a pre-sustainability-intervention engineering curriculum.

Another limitation to the study is the ability of HEI stakeholders to accurately assess the engineering programmes based on the sustainability themes. Stating the extent to which a topic is covered in an engineering programme can be somewhat challenging. Both students and educators could be limited in their responses by a number of factors including memory errors and misapprehension of the assessment gauge. Memory error could be an important challenge as it is not unusual for students to disremember course contents especially of programme units previously taken. Students' failure to recall the details of courses in their engineering programmes could hinder their ability to correctly assess them for sustainability coverage. Relatedly, unfamiliarity with the sustainability topics could lead to a misreading of the themes-based assessment gauge that may eventually affect appraisal of the programmes.

None of these challenges significantly impacted on the study as responses were not only plausible but also reflective of the documentary assessments. Additionally, the involvement of both penultimate year and final year undergraduate students in the study as well postgraduate students reduced the effect of memory gaps. As for the possible misreading of the assessment criteria little can be done to mitigate the situation. Fortunately, such misconstrual is an important part of the stakeholders' subjective experience of the engineering curriculum, which is relevant to the study.

Summary

Results of a sustainability content analysis of the Nigerian engineering curriculum were presented in the chapter. The assessment involved the official BMAS for engineering programmes as well as engineering documents and the perspectives of stakeholders (n=316) from two Nigerian HEIs. These data were tested against 37 sustainability topics obtained from an expert-derived list of sustainability themes. An outcome of the study was that the sustainability content of the engineering programmes based on the documentary analysis was low at a mean spread of 4.3% (13.37% average potential content). Similarly, only one-third of the stakeholders (33.7%) regarded sustainability topics as contained “strongly” or “to a great extent” in the engineering curriculum. Furthermore, environmental concepts were the most cited sustainability themes, whilst social topics were the least stated issues in the curriculum.

Most of the sustainability topics appeared in the traditional engineering management courses. Only the BMAS document mentioned sustainability competence as a learning outcome for engineering graduates. A comparative look at the sustainability contents of the UCL and the Nigerian engineering curricula revealed a commonality in the core disciplines, with the UCL Civil and UCL Chemical Engineering being the exceptions. Although the UCL engineering curriculum was found to contain more sustainability topics, the efficacy of such content in terms of sustainability literacy cannot be guaranteed. Overall, the findings confirmed the need for a sustainability education intervention for the Nigerian engineering curriculum. The question of an appropriate sustainability education intervention for the curriculum is addressed in *Chapter Seven.*

Chapter Seven

7 Sustainability Education for Nigerian Engineering Curriculum

Introduction

This chapter responds to the question: *What sustainability education interventions are appropriate for the Nigerian engineering curriculum?* Answers to the question were informed by stakeholder responses to a survey (n=442) as well as insights from the preceding chapters. The chapter proceeds by stating some useful intervention cues before analysing the stakeholders' views on various intervention approaches. The chapter concludes with a discussion of the findings and limitations of the study.

Intervention Cues

Some useful pointers to the prospect of a sustainability education intervention in the Nigerian engineering curriculum were observed in the study. These included the likely existence of sustainability courses in Nigerian HEIs, current source of sustainability knowledge in the HEIs, and stakeholders' perception of the sustainability content of engineering courses in the HEIs.

Existence of Sustainability Courses in Nigerian HEIs

HEI stakeholders (n =316) were asked whether a sustainability course or programme was offered in their institutions. The majority of the stakeholders (66.7%) responded in the negative with only one-third admitting the existence of at least a sustainability course in their HEIs (Table 7.1). Disaggregating the data by institution and cohort revealed no statistically significant differences ($p \leq 0.001$). Hence, sustainability courses or programmes were perceived as largely non-existent in Nigerian HEIs.

Table 7.1. Stakeholders' views on existence of a sustainability course in HEIs

***Survey prompt**: Does your university offer a sustainability course, module or degree?* n = 316		Frequency	Percent
	Yes	105	33.3
	No	211	66.7
	Total	316	100.0

Sources of Sustainability Knowledge in Nigerian HEIs

Educators and students assessed the extent to which they had taught and learned about sustainability through various means and sources. Results of the assessment are presented in the succeeding sections.

Sustainability Learning

Table 7.2 shows results of students' perception of the means of sustainability learning. More than half of the students ($\boldsymbol{\phi}_{4\text{-}5}$ = 52.2%) indicated that the media (TV, radio, internet, etc.) was a great source of sustainability knowledge. A little over one-third of the students ($\boldsymbol{\phi}_{4\text{-}5}$ = 34.4%) considered the common engineering courses as an important source of sustainability knowledge. Similarly, one-third of the students ($\boldsymbol{\phi}_{4\text{-}5}$ = 33.9%) felt that they had learned about sustainability either "strongly" or "to a great extent” through the core engineering courses. Participation in an undergraduate or postgraduate research was considered as a significant source of sustainability knowledge by only 3 in 10 students (ϕ_{4-5} = 31.4%).

Table 7.2. Students’ views on source of sustainability knowledge

Survey Prompt: *Indicate the extent to which you have learned about sustainable development through the following.*												
Stakeholder	Core Engineering Courses			Common Engineering Courses			UG or PG Research			Media Sources (TV, radio, etc.)		
	ϕ_{1-2} (%)	ϕ_{3} (%)	ϕ_{4-5} (%)	ϕ_{1-2} (%)	ϕ_{3} (%)	ϕ_{4-5} (%)	ϕ_{1-2} (%)	ϕ_{3} (%)	ϕ_{4-5} (%)	ϕ_{1-2} (%)	ϕ_{3} (%)	ϕ_{4-5} (%)
HEI-1 (n=137)	32.6	32.6	34.9	28.0	38.0	34.1	25.8	42.2	32.1	15.6	27.9	56.6
HEI-2 (n=95)	35.7	31.6	32.6	26.3	38.9	34.8	44.2	25.3	30.5	24.2	29.5	46.8
Total (n=232)	**33.9**	**32.1**	**33.9**	**27.2**	**38.4**	**34.4**	**33.6**	**35.0**	**31.4**	**19.2**	**28.6**	**52.2**

Note: ϕ_{1-2} signifies “not at all” and “slightly”; ϕ_{3} represents “moderately”, while ϕ_{4-5} symbolises “strongly” and “to a great extent”

Sustainability Teaching

Table 7.3 presents the results of educators’ evaluation of the various means of imparting sustainability knowledge. Over two-fifths of the educators (ϕ_{4-5} =41.7%; ϕ_{4-5} = 42.8%) specified that they had taught about sustainability “strongly” or “to a great extent” by supervising an academic research and by pointing students to media sources respectively. Nonetheless, less than one-third of the educators (ϕ_{4-5} = 31.0%; ϕ_{4-5} = 32.1%) considered core engineering and common/elective courses respectively as a great means of teaching about sustainability.

Table 7.3. Educators' views on means of sustainability teaching

Survey Prompt: *Indicate the extent to which you have taught about sustainable development through the following.*												
Stakeholder	Core Engineering Courses			Common Engineering Courses			UG or PG Research			Media Sources (TV, radio, etc.)		
	ϕ_{1-2} (%)	ϕ_{3} (%)	ϕ_{4-5} (%)	ϕ_{1-2} (%)	ϕ_{3} (%)	ϕ_{4-5} (%)	ϕ_{1-2} (%)	ϕ_{3} (%)	ϕ_{4-5} (%)	ϕ_{1-2} (%)	ϕ_{3} (%)	ϕ_{4-5} (%)
HEI-1 (n=55)	36.3	32.7	30.9	36.3	32.7	30.9	25.5	40.0	34.5	23.6	43.6	32.7
HEI-2 (n=29)	24.1	44.8	31.0	20.6	44.8	34.4	6.8	37.9	55.2	6.9	31.0	62.1
Total (n=84)	**32.1**	**36.9**	**31.0**	**30.9**	**36.9**	**32.1**	**19.0**	**39.3**	**41.7**	**17.8**	**39.3**	**42.8**

Note: ϕ_{1-2} signifies “not at all” and “slightly”; ϕ_{3} represents “moderately”, while ϕ_{4-5} symbolises “strongly” and “to a great extent”

Summary of Stakeholders' Views on Sources of Sustainability Knowledge

Table 7.4 summarises the perspectives of the stakeholders on the extent to which sustainability has been learned and taught in the Nigerian HEIs. Media sources were recognised by a significant proportion of educators and students as a great means of acquiring sustainability knowledge. The least acknowledged means or sources of sustainability knowledge from the standpoint of the stakeholders were the core engineering courses. However, a difference of opinion was observed regarding the effectiveness of acquiring sustainability knowledge by means of an academic research. More educators than students considered scholarly research as a vital means of learning about sustainability.

Table 7.4. Summary of stakeholder views on sustainability knowledge source

Sustainability Knowledge Source	Learned $\phi_{4\text{-}5}$ (%) (n=232)	Taught $\phi_{4\text{-}5}$ (%)(n=84)	Mean (%)
Core Engineering Courses	33.9	31.0	32.5
Common/Elective Courses	34.4	32.1	33.3
UG or PG Research	31.4	41.7	36.6
Media Sources	52.2	42.8	47.5

Note: $\phi_{1\text{-}2}$ signifies "not at all" and "slightly"; ϕ_3 represents "moderately", while $\phi_{4\text{-}5}$ symbolises "strongly" and "to a great extent"

Perceived Sustainability-Related Courses

HEI stakeholders (n=316) were asked to mention three courses which in their opinion covered sustainability issues. This resulted in a list of 138 different courses (see Appendix XI). Figure 7.1 depicts 25 of the most frequently occurring courses (>5% frequency), whilst Table 7.5 is a distribution of the perceived sustainability courses. From the chart and table, the common/elective course of *Engineer in Society* and the core engineering course of *Environmental Impact Assessment* were perceived as the most sustainability-relevant courses. Also, *Research Methodology*, a common/elective course, and *Systems Reliability*, a core engineering course, ranked relatively high on the sustainability-related courses list. Nearly all the mentioned sustainability-related core engineering courses hinted at an environmental aspect of sustainability. With the exception of *Systems Reliability*, which was mentioned by only stakeholders in the engineering programmes of electrical, mechanical, and systems engineering, the core engineering courses seemed bereft of the economic, social and crosscutting aspects of sustainability. The extent to which a number of these courses and programmes addressed sustainability had already been assessed (*Chapter Six*). Interestingly, none of the perceived sustainability-related courses had been entitled "*Sustainable Engineering."* This was an important pointer to the need for a sustainability education intervention in the Nigerian engineering curriculum.

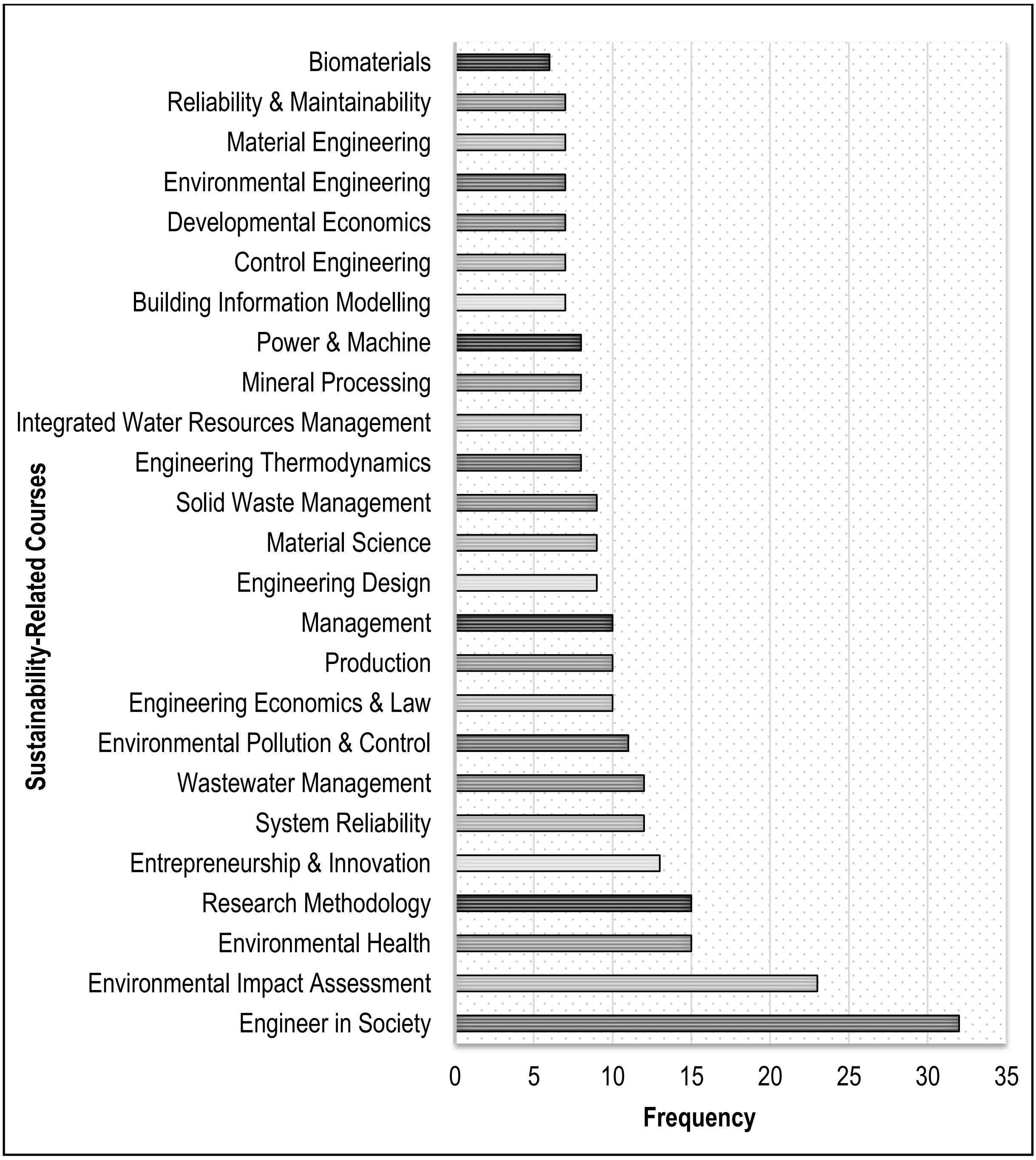


Figure 7.1. Top 25 perceived sustainability-related courses

Table 7.5. Distribution of perceived sustainability-related courses

Core Engineering Course	Programme	Common/Elective Course	Programme
Environmental Impact Assessment	Chemical, Civil, Environmental, Metallurgical, and Water Engineering	Engineer in Society	All programmes
Environmental Health	Agricultural, Environmental, Public Health, and Water Resources Engineering	Research Methodology	All programmes
System Reliability	Electrical, Mechanical, and Systems Engineering	Entrepreneurship & Innovation	All programmes
Wastewater Management	Civil, Water Resources, and Environmental Engineering	Engineering Economics	All programmes
Environmental Pollution	Chemical, Environmental, and Petroleum Engineering	Engineering Law	All programmes
Material Science	Chemical, Electrical, Mechanical, Metallurgical, and Petroleum Engineering	Engineering Management	All programmes
Solid Waste Management	Civil, Environmental, and Public Health Engineering	Engineering Design	All programmes
Mineral Processing	Metallurgical, Mining, and Production Engineering	Engineering Thermodynamics	All programmes
Power & Machine	Electrical, Industrial, Mechanical, and Mechatronics Engineering	Engineering Materials	All programmes
Biomaterials	Biomedical, Chemical, Metallurgical, and Petroleum Engineering	Developmental Economics	All programmes

Sustainability Importance

The Nigerian engineering community (n=442) responded to three questions on the importance of sustainability. Answers to these queries are presented in the succeeding sections under the subheadings of sustainability support, sustainability expertise, and sustainability education.

Sustainability Support

Table 7.6 shows the response of the Nigerian engineering community on whether Nigerian engineers should contribute to sustainable development. A vast majority of the respondents (88.4%) agreed or strongly agreed with the sustainability support statement. Disaggregating the data by groups revealed no statistically significant differences ($p \leq 0.001$). Thus, it was generally accepted that Nigerian engineers should not only be involved in sustainability, but actively support it.

Table 7.6. Stakeholders' views on engineers' support of sustainability

Survey prompt*: Nigerian engineers should contribute to sustainable development* n = 442		Frequency	Percent
	Strongly disagree	34	7.7
	Disagree	5	1.0
	Neutral	13	2.9
	Agree	94	21.3
	Strongly agree	296	67.1
	Total	442	100

Sustainability Expertise

Table 7.7 shows the response of the Nigerian engineering community on whether Nigerian engineers should acquire a sustainability expertise. An overwhelming majority of the respondents (80.5%) agreed or strongly agreed with the sustainability expertise statement. There were no statistically significant differences across the groups ($p \leq 0.001$). Thus, it was largely accepted that sustainability expertise was a competence required of Nigerian engineers.

Table 7.7. Stakeholders' views on engineers' need of sustainability expertise

Survey prompt*: Sustainability expertise is a competence required of Nigerian engineers* n = 442		Frequency	Percent
	Strongly disagree	31	7.0
	Disagree	10	2.3
	Neutral	45	10.2
	Agree	161	36.4
	Strongly agree	195	44.1
	Total	442	100

Sustainability Education

Table 7.8 presents the response of the Nigerian engineering community on whether sustainability is important in engineering education. A substantial majority of the respondents (87.8%) agreed or strongly agreed with the sustainability education statement. Disaggregating the data by cohorts revealed no statistically significant differences ($p \leq 0.001$). Thus, it was commonly accepted that sustainability was essential in engineering education.

Table 7.8. Stakeholders' views on sustainability in engineering education

Survey prompt*: Sustainability is important in engineering education* n = 442		Frequency	Percent
	Strongly disagree	32	7.3
	Disagree	5	1.1
	Neutral	17	3.8
	Agree	119	26.9
	Strongly agree	269	60.9
	Total	442	100

Stakeholder Intervention Views

Stakeholders were queried on the best suitable intervention approach and on their general views about sustainability and engineering education in Nigeria. The following sections present the results of these inquiries.

Intervention Approach

Engineering stakeholders were asked to indicate the appropriateness or otherwise of introducing sustainability education via integration into existing core courses, creation of new discipline-specific course, creation of new cross-disciplinary courses, and integration into common/elective courses.

Existing Core Course

Table 7.9 shows the response of the Nigerian engineering community on the suitability of the existing core courses as a means of introducing sustainability in the Nigerian engineering curriculum. A large proportion of the stakeholders (63.6%) expressed the view that the existing core courses were "strongly" or "extremely" appropriate for such intervention. There were no statistically significant differences across groups ($p \leq 0.001$). Thus, the integration of sustainability into existing core engineering courses or programmes was largely considered a suitable intervention approach.

Table 7.9. Stakeholders' views on intervention via core courses

Survey prompt*: Integration of sustainability into existing core courses or programmes n=425*		Frequency	Percent
	Not at all	17	4.0
	Slightly	36	8.5
	Moderately	102	24.0
	Strongly	183	43.1
	Extremely	87	20.5
	Total	425	100

Discipline-Specific Course

Table 7.10 shows the response of the Nigerian engineering community on the suitability of the discipline-specific course as a means of introducing sustainability in the Nigerian engineering curriculum. Just over half of the stakeholders (52.7%) expressed the view that the discipline-specific course was “strongly” or “extremely” appropriate for such intervention. Disaggregating the data by groups revealed no statistically significant differences ($p \leq 0.001$). Thus, the creation of a new discipline-specific sustainability course or programme was not overwhelmingly considered a suitable intervention approach.

Table 7.10. Stakeholders' views on intervention via discipline-specific courses

Survey prompt*: Creation of new discipline-specific courses or programme n=425*		**Frequency**	**Percent**
	Not at all	17	4.0
	Slightly	47	11.1
	Moderately	137	32.2
	Strongly	148	34.8
	Extremely	76	17.9
	Total	425	100

Cross-Disciplinary Course

Table 7.11 presents the response of the Nigerian engineering community on the suitability of a cross-disciplinary course as a means of introducing sustainability in the Nigerian engineering curriculum. A little over half of the stakeholders (53.7%) expressed the view that the cross-disciplinary course was “strongly” or “extremely” appropriate for such intervention. There were no statistically significant differences across the cohorts ($p \leq 0.001$). Thus, the creation of a new cross-disciplinary sustainability course or programme was fairly considered a suitable intervention approach.

Table 7.11.Stakeholders' views on intervention via new cross-disciplinary course

Survey prompt*: Creation of new cross-disciplinary sustainability course or programme n=425*		**Frequency**	**Percent**
	Not at all	20	4.7
	Slightly	49	11.5
	Moderately	128	30.1
	Strongly	160	37.6
	Extremely	68	16.1
	Total	425	100

Common/Elective Course

Table 7.12 shows the response of the Nigerian engineering community on the suitability of the common/elective courses as a means of introducing sustainability in the Nigerian engineering curriculum. A sizable proportion of the stakeholders (58.6%) expressed the view that the common/elective core courses were “strongly” or “extremely” appropriate for such intervention. Disaggregating the data by groups revealed no statistically significant differences ($p \leq 0.001$). Thus, the integration of sustainability into common/elective engineering courses was generally considered a suitable intervention approach.

Table 7.12. Stakeholders' views on intervention via common/elective courses

***Survey prompt**: Integration of sustainability into common/elective engineering courses n=425*		Frequency	Percent
	Not at all	14	3.3
	Slightly	34	8.0
	Moderately	128	30.1
	Strongly	163	38.4
	Extremely	86	20.2
	Total	425	100

Summary of Stakeholder Intervention Views

Table 7.13 is a summary of stakeholders’ views on the suitable education intervention approach for Nigerian engineering curriculum. Only the percentages of “strongly” and “extremely” ($\theta_{4\text{-}5}$) responses are depicted.

Table 7.13. Summary of stakeholders' views on intervention approach

***Survey Prompt**: Indicate how appropriate the following ways of introducing sustainability education would be to an engineering curriculum* (n=425)	**$\theta_{4\text{-}5}$ (%)**
Integration into existing core course	63.6
Integration into common/elective course	58.6
Creation of new cross-disciplinary course	53.7
Creation of new discipline-specific course	52.7

Note: $\boldsymbol{\theta_{4\text{-}5}}$ signifies “strongly” and “extremely” responses

General Comments

An open-ended question sought stakeholders’ opinion on engineering education and sustainability in Nigeria. The survey prompt read thus: *Please add comments that you have about sustainability and engineering education in Nigeria.* Four themes emerged from an analysis of the elicited responses. The themes, which were all framed from an intervention standpoint, included approach, challenge, focus area, and imperative.

Intervention Approach

Several of the comments from the Nigerian engineering stakeholders were ideas about intervention approaches. Members of the three groups within the engineering community in Nigeria remarked on ways a sustainability education intervention could be successfully achieved. Some of the stakeholders suggested a top-down approach maintaining that "there should be a law guiding the implementation of sustainability in our universities" [ER65]. A practitioner more explicitly stated that the "government need to make a legislation to guide…sustainability [in] engineering education" [PR104]. Also, notions of a holistic approach were echoed by a number of the stakeholders, to wit: "Sustainability and engineering education can only be realistic when addressed from a holistic standpoint" [SR102]. Another respondent remarked that "emphasis should not be limited to the academic level, but also extended to the general public" [SR157]. Other intervention approaches cited by the stakeholders included alignment with global best practice: "…needs to be reviewed to be (sic) in line with international practices" [ER33], seminars: "…seminars should be organised to create awareness" [SR125], and use of add-on approaches: "Sustainability should be introduced as a local content added to the engineering syllabus" [SR177]. A summary of the stakeholder-suggested intervention approaches is presented in Table 7.14.

Intervention Challenge

Likely challenges of a sustainability education intervention for the Nigerian engineering curriculum emerged from the general comments of the stakeholders. Lack of political will was mentioned as a challenge to the intervention with some participants describing it as "the greatest challenge" [ER4]. Another possible constraint suggested by the stakeholders was poor sustainability knowledge, which some felt could hinder "implementation of these (sic) knowledge" [ER30]. Respondents also mentioned corruption in government as a possible encumbrance of a successful sustainability education intervention. One respondent explained the corruption charge thus: "[It is] difficult to adopt sustainability because of corruption and corporate interest of those that benefit from status quo (sic)" [ER18]. Some stakeholders opined that, in addition to profiteering by interest groups, lack of capacity could impede any sustainability education intervention. In the words of one respondent, “Government lacks capacity to implement reports sent to them” [ER4]. Still on the issue of capacity a student stated that “the potential [of an intervention] in the present national development is poor” [SR161]. Overall, the suggested challenges indicated stakeholders’ interest in the success of a sustainability education intervention. A summary of the stakeholder-suggested intervention challenge is presented in Table 7.14.

Intervention Focus Area

Results revealed that stakeholders considered several topics as essential in a sustainability education intervention. An important focus area stressed by respondents was research. Stakeholders opined that an education intervention should comprise a practical research element as “we have more theoretical engineers than practical engineers” [SR101]. Focusing on a praxis-oriented sustainability research was thus suggested as a possible mitigation. Another subject of interest to the stakeholders was technology policy. An engineering educator cited “energy efficient processes and low environmental emission products” [ER50] as examples of areas that can be covered under technology policy within a sustainability education intervention. Other focus areas recommended by the stakeholders included EIA, LCA, engineering design, renewables, and construction methods, all of which corresponded to the previously highlighted sustainability-related courses (see Table 8.5). On the whole, the Nigerian engineering community were interested in an effective and meaningful sustainability education for the Nigerian engineering curriculum. A summary of the stakeholder-suggested focus areas is presented in Table 7.14.

Intervention Imperative

Stakeholders expressed opinions on the importance of a sustainability education intervention for the Nigerian engineering curriculum. These views ranged from ideas on the need to integrate sustainability into the engineering education to opinions on the benefits of the intervention. One respondent declared that “Nigeria needs sustainability engineering education” [ER12], and another participant stated that “Sustainability in engineering teaching and practice should be encouraged and practised” [PR27]. These sustainability imperatives were repeatedly stressed by the stakeholders. Some respondents underscored such intervention merit as the potential “to improve the quality of engineering education in Nigeria” [SR18]. Another intervention imperative also highlighted by the stakeholders was self-reliance. A respondent averred that a sustainable engineering education could contribute towards Nigeria “becoming more productive and less dependent on other countries” [ER31]. The acquisition of contemporary problem-solving skills was equally stated as an intervention benefit. In general, the Nigerian engineering community expressed strong conviction on the need for a sustainability education intervention in the engineering curriculum. A summary of the stakeholder-suggested intervention imperatives is presented in Table 7.14.

Table 7.14. Summary of emergent themes from stakeholders' comments

Themes	Description	Examples
Approach	Stakeholders' views on the appropriate method to be used in any effort to introduce sustainability education in Nigerian engineering curriculum	Top-down approach, holistic method, existing core courses, new discipline-specific course, global best practice model, government policy, add-on, seminars, common engineering courses
Challenge	Stakeholders’ views on the likely challenges of a sustainability education intervention for Nigerian engineering education	Lack of political will, poor sustainability knowledge, corruption in government, lack of capacity, profiteering by interest groups, poor record of successful policy implementation
Focus Area	Perspectives of stakeholders on the areas that a sustainable engineering course or module in Nigerian engineering curriculum should feature or cover	Research, biofuels, jobs, industrial activities, training, EIA, LCA, energy efficiency, engineering design, emissions, technology policy, construction methods, renewables
Imperative	Stakeholders’ views on the importance of a sustainability education intervention for Nigerian engineering, including ideas on why sustainability should be integrated into the engineering programmes	Economic growth, social responsibility, self-reliance, protection imperative, reorientation of engineers, need for sustainability awareness, potential to improve engineering education, acquisition of problem-solving skills

Discussion

Lack of Sustainability Courses in the HEIs

The question to stakeholders on whether a sustainability course, module or degree exists in their HEIs is multi-objective. Firstly, it seeks to establish from the perspective of the stakeholders the occurrence of any form of sustainability learning or teaching in the HEIs. Secondly, it serves as a crosscheck on the results of the sustainability content analysis of the engineering documents (*Chapter Six*). Finally, it conduces to the aim of revealing the prospect of a sustainability education intervention in the Nigerian engineering curriculum. By the admission of the stakeholders, sustainability courses, modules or degrees are largely non-existent in the Nigerian engineering education. This finding is not unusual for an engineering curriculum that has not been purposefully imbued with sustainability ideals (*Chapter Three*). However, the fact that a few of the stakeholders admit, at the very least, the existence of a sustainability course in the HEIs is quite interesting. What is undeniable is the absence of an undergraduate or a postgraduate degree programme on either sustainability or sustainable engineering in the curriculum. The literature review undertaken in the present study and the sustainability content analysis of the Nigerian engineering curriculum (see *Chapter Six*) equally point to such deficiency.

As for the existence of a sustainability course or module in the HEIs, it is likely that some of the respondents have based their judgements on the few sustainability topics extant in the curriculum. Corroborating this account is the stakeholder-provided sustainability courses list in which some courses, such as *Environmental Health, Environmental Impact Assessment* and *Developmental Economics* are evidently sustainability-related. This is also consistent with the findings of the sustainability curricular assessment presented in *Chapter Six*. However, several of these courses are not featured in all the engineering programmes. Therefore, it is plausible that not all the respondents will acknowledge them in a survey, which may explain the minority contrarian views. It is, thus, reasonable to deduce that for the great majority of the engineering community sustainability courses or modules are largely non-existent.

What the lack of sustainability courses or degrees in Nigerian HEIs implies is the plausibility of an intervention. However, the extent to which the absence of a pedagogical element translates to a propitious intervention prospect is thought-provoking. Obviously, the lack of a sustainability course in the Nigerian engineering curriculum provides a cogent argument for a sustainability education intervention. This point, although useful in grounding an intervention proposal, may not sustain the process through to implementation. As numerous studies have shown, sustainability courses are not designed and embedded into engineering programmes simply as a result of their absence (Azapagic *et al.*, 2005; Allenby *et al.*, 2009; Murphy *et al.*, 2009). Amongst several other factors, support mechanisms have to be incorporated in a prospective intervention to achieve success. This constraint has been identified and is catered for in the sustainability education intervention proposed in *Chapter Eight*.

Perceived Sources of Sustainability Knowledge

Stakeholders vary in perception of the means of sustainability learning and teaching in Nigerian HEIs. Whilst a consensus exists on some of the sources of sustainability knowledge, there are also some marked disagreements (see Table 7.4). The points of agreement are on the roles of core engineering and common/elective courses as sources of sustainability knowledge. Both educators and students express low opinion of these sustainability knowledge sources, which implies that sustainability learning and teaching have barely occurred through these means. This finding is expected given the long-standing focus of core engineering courses on fundamental topics and the limits of extant common/elective courses in the Nigerian engineering curriculum. Some studies have already shown that core engineering courses are typically bereft of sustainability concepts, especially prior to an intervention (Fenner *et al.*, 2005). The sustainability content analysis of engineering documents in the present study (see *Chapter Six*) yielded similar results.

The point of divergence between educators and students is on the extent to which sustainability teaching and learning have occurred via undergraduate or postgraduate research. The students fail to corroborate the educators' views that academic research is a crucial means or source of sustainability knowledge in the Nigerian HEIs. The inability of the students to recognise any form of sustainability learning by undertaking an academic research in spite of the educators suggesting the contrary is quite interesting. Could be this be as a result of poor appreciation of what constitutes sustainability knowledge? Or could it simply be a consequence of a gap between what is taught and what is learned? In other words, educators might have taught about sustainability during supervision of an academic research, but the students might have missed this teaching point.

With regards to the possibility that a poor grasp of sustainability might have contributed to the difference of opinion between the educators and students, it is likely that such deficit could have played a part. However, the findings of the present study and the various concept clarifications featured in the survey (see *Chapter Four*), such as the catalogue of sustainability themes and a definition of sustainability do not support this explanation. Since sustainability was appropriately defined in the context of the present study, failure to appreciate the constituents of sustainability knowledge may not be a pertinent account. Nevertheless, the argument that a communication gap between educators and students has been responsible for the differing views seems plausible. Indeed, relationship between teaching and learning has been the subject of intense study in educational research (McFarland, 2005; Kullberg, 2010). Results have typically pointed to a mismatch between the perceptions of educators on the efficacy of their teaching and the learning experiences of students (Kullberg, 2010).

What is wanting in adducing this explanation for the conflicting views in the case of the Nigerian engineering educators and students is the sustainability literacy level of the educators. Findings of the present study revealed that an equal level of sustainability literacy subsisted for both educators and students (see *Chapter Five*). Consequently, it will be flawed to assume that the educators mentioned sustainability issues at academic research meetings which the students did not heed. However, there is an interesting point of convergence between the educators and the students on the effectiveness of media sources for sustainability knowledge. Media platforms such as educational television, radio, newspapers, Internet, etc. have been recognised as a great source of sustainability knowledge in some sustainability studies (Mcfarlane and Ogazon, 2011; UNESCO, 2012; Fadeeva *et al.*, 2014). The use of these sources could be included in an introductory sustainability course as part of sustainability education intervention for the Nigerian engineering curriculum.

Parikh and McRobie (2009) reported the positive impacts of television on the education of a community in Sanjaynagar slum in India. Many slum residents admitted to benefitting from programmes aired on such TV stations as Discovery channel, etc. An evidence of a change in lifestyle ascribed to TV viewing is suggested (Parikh and

McRobie, 2009). The claim by the members of the Nigerian engineering community to have accessed sustainability knowledge via media sources is therefore important. This could be enhanced by providing an additional engineering sustainability material to the TV content. Through a collaboration with local TV stations, the COREN, FMEnv and the RCEs could sponsor sustainability-related programmes that would be presented regularly nationwide. Examples of such programmes are the role of Nigerian engineers in the realisation of SDGs and the engineering sustainability opportunities in Nigeria.

Distribution of Perceived Sustainability-Related Courses

The intent of asking stakeholders to mention three courses which they regard as addressing sustainability is to identify and double-check the existence of sustainability courses in the Nigerian HEIs. The question is also a corollary of the goal to weigh the prospect of an intervention. Interestingly, the query produced more than 100 topics with some themes clearly unrelated to sustainability as conceptualised in the present study. Examples of such extraneous courses listed by the stakeholders are *Statistics for Engineers* and *Atomic Spectra.* Several reasons could account for the mention of these non-sustainability-related courses. The stakeholders who listed such courses might have been motivated by the need to identify sustainability issues with their engineering programmes. Reputational concerns such as being the only HEI or engineering discipline devoid of any sustainability courses could influence some stakeholders to respond tangentially. Indeed, the findings from the sustainability import statements discussed in the next section show that stakeholders overwhelmingly support sustainability education. Hence, it is likely that some of the stakeholders are keen to identify some engineering courses with sustainability in order to portray their HEIs or disciplines as sustainability-friendly.

Of the top 25 sustainability-relevant courses listed by the stakeholders, some are classified as core engineering courses whilst others fall under the common/elective courses category (Table 7.5). The distribution of these courses in this way has important implications for the study. Most of the sustainability-related courses are biased towards environmental sustainability, but are also taught exclusively as core courses in a few of the engineering programmes. This corroborates a previous explanation of findings in the present study, which defers to the restriction of the environmental topics to a smattering of the engineering students as a reason for stakeholders’ low familiarity with environmental issues (*Chapter Five*). For the courses that fall under the common/elective category, the extent to which they contain sustainability issues has already been found to be insufficient (see *Chapter Six*). Additionally, the fact that none of the listed courses is prefixed or affixed with a sustainability label further confirms the lack of concerted efforts to embed sustainability in the engineering curriculum. To address these inadequacies, a sustainability-titled introductory course has been designed around the four sustainability themes featured in the present study and proposed to be taught as a common/elective engineering course (*Chapter Eight*).

Sustainability Import Statements

The three sustainability statements in the context of Nigerian engineering seek to ascertain the disposition of engineering stakeholders in Nigeria towards supporting sustainability, sustainability expertise and sustainability education. An overwhelming majority of the stakeholders (>80%) are favourably disposed towards all the three propositions. This finding is comparable to the outcome of a survey administered world-wide by Azapagic et al. (2005) to engineering students in around 40 universities. Nearly all the engineering students surveyed by the researchers thought sustainable development was important for them personally and professionally. By admitting that Nigerian engineers should contribute to sustainable development, the stakeholders in Nigeria could be expressing a willingness to actively participate in engineering sustainability. This prospect is enhanced by the concurrence of the stakeholders that sustainability expertise is a competence required of all Nigerian engineers. Hence, an engineering community with such proclivity for sustainability may have little difficulty imbibing the principles of sustainable engineering.

The enormous support for sustainability education shown by the Nigerian engineering community is also encouraging. It demonstrates that stakeholders appreciate the existing gap in the Nigerian engineering curriculum and the need to proffer an effective and meaningful solution. To acknowledge the presence of a problem is commonly considered a critical first step towards solving it. This is particularly relevant realising that all the three groups of the Nigerian engineering community, namely practitioners, educators, and students share these views. Therefore, it is well within reason to envisage that the engineering practitioners in Nigeria, for example, will seek to educate themselves about sustainability post-intervention. This could even be an impetus for the creation of a postgraduate course on engineering sustainability akin to UCL's MSc in Sustainable Resources or the University of Cambridge's MPhil in Engineering for Sustainable Development. Designing such postgraduate degree, however, is beyond the scope of the present study and could form part of a future sustainability education research for Nigeria.

Closed-Ended Responses

The closed-ended question seeks stakeholders' views on the appropriateness of an intervention via core courses, common courses, new cross-disciplinary course, and new discipline-specific course. Responses to the closed-ended question favour an intervention via core courses and common courses, although more than half of the respondents regard all the approaches as suitable. However, the cross-disciplinary and discipline-specific courses are inherently problematic and resource-intensive (Rusinko, 2010) and may not be appropriate for an introductory course such as proposed in the present study. This is not to say that the approaches cannot be considered by Nigerian HEIs that have the capacity and wherewithal to manage them successfully. Indeed HEIs in Nigeria that may consider offering a postgraduate degree on sustainable engineering will find either the cross-disciplinary or the discipline-specific approaches useful. Nonetheless, the stakeholders' preference based on the closed-ended responses is integration via the core courses and the common courses respectively.

This finding is congruent with several sustainability education studies (Perdan, Azapagic and Clift, 2000; Desha *et al.*, 2007; Sinnott and Thomas, 2012; von Blottnitz *et al.*, 2015). Intervention via core engineering courses has been documented as the best suitable way of integrating sustainability in an engineering curriculum. However, studies have equally recognised the challenges associated with employing the core engineering courses in the integration of sustainability into an education curriculum. An oft-cited disadvantage of this approach is the administrative hiccup occasioned by a cramped engineering curriculum (Allenby *et al.*, 2009; Rusinko, 2010). In the case of the Nigerian engineering curriculum which grapples with not only a packed content but also legacy issues (see *Chapter Three*), intervention via the core courses is not a suitable option for a trial introductory course; hence the choice of the common courses proposed in *Chapter Eight*. Nevertheless, integrating sustainability into the core courses of the Nigerian engineering curriculum could be an ultimate intervention desire.

Open-Ended Responses

The open-ended question invites stakeholders to comment on sustainability and engineering education in Nigeria, which opportunely produced intervention-oriented responses. The general comments of the stakeholders from the open-ended question evince not only an exigency but a high sense of pragmatism. Having established the imperative of sustainability in Nigerian engineering education and practice, the stakeholders comment variously on intervention focus area, suitable approach, and possible challenge. On the imperative of sustainability education in the Nigerian engineering curriculum, the stakeholders' comments match several ideas in the literature reviewed in the present study (see *Chapter Two*). With a list of sustainability benefits such as economic growth and self-reliance as well as the potential to improve engineering education in Nigeria and acquire complex problem-solving skills, the stakeholders exhibit a good appreciation of the sustainability imperative. This is consistent with the findings from the closed-ended question regarding the import of sustainability in the Nigerian engineering context. Similarly, the focus areas suggested in the comments of the stakeholders correspond to the gaps noticed in the curricular sustainability content analysis (see *Chapter Six*). These have been considered in the course design undertaken in *Chapter Eight*.

With respect to the intervention approach, the variously cited examples ranging from top-down and holistic method to intervention via the common courses and global best practice, a pragmatic undertone is apparent. The stakeholders seem to generally advocate a pragmatic intervention approach, i.e. a success-oriented approach given the Nigerian context. This is especially pertinent recognising that nearly half of the respondents are engineering educators and practitioners who might have served in different positions of educational policy-making in Nigeria. Practical considerations are invaluable in such situations and most useful in a sustainability education intervention for the Nigerian engineering curriculum. A number of studies have indicated the contingency of success on the contextual practicalities of sustainability education in a given setting. The three-tier approach to teaching about sustainability developed by

Azapagic *et al* 2005 is underlain by pragmatism evident in its incremental character. These pragmatic ideas are reflected in the guideline for intervention developed in the present study (see *Chapter Eight*).

Limitations

One of the limitations acknowledged in the study is the likely inability of the students to accurately identify appropriate intervention approaches. Since Nigerian engineering students are rarely involved in curricular development or course designs, they might not be conversant with how best to introduce a course in the engineering curriculum. Consequently, asking students to indicate the appropriateness of an intervention approach may simply lead to conjecture. The extent to which guesswork might have occurred in the students' responses cannot be ascertained. However, being the primary recipients of knowledge via the designed curriculum, students might have ideas of the various approaches, especially as course categories. Such familiarity with the curriculum could enable them to recognise the most effective course categories, which may be handy in responding to the survey. Nonetheless, as the findings of the study revealed no statistically significant differences, the possibility of conjecture is low.

Another limitation of the study is the possibility of bias in the mentioned sustainability-related courses. Since the resulting list is a function of frequency, courses offered by an overrepresented engineering programme could rank higher than others. For example, *Systems Reliability*, which is a core course in only electrical, mechanical and systems engineering, ranked sixth on the list of the top 25 most frequent sustainability-related courses. Such drawback could affect the findings of the study by yielding a false result, making a listed course appear more pervasive than it actually is. However, the collection of data on course type (core or common) alongside the listed courses was an effective countermeasure employed in the present study against this bias. The piece of information was a valuable filter of the pervasiveness and relevance of the perceived sustainability-related courses.

Summary

An assessment was conducted to address the question of what sustainability education interventions are appropriate for the Nigerian engineering curriculum. This involved an analysis of a stakeholder survey (n=442). On the prospect of an intervention, a significant majority (70%) of the stakeholders admitted a lack of sustainability courses or programmes in the Nigerian engineering curriculum. In addition, almost half of the stakeholders (47.5%) pointed to media sources (TV, Internet, etc.) as the means of acquiring sustainability knowledge. Core engineering and common courses were considered the least sources of sustainability knowledge. Educators and students disagreed on the extent of gaining sustainability knowledge via an academic research with the former expressing positive views and the latter suggesting the contrary.

For sustainability-related courses, the common course of *Engineer in Society* was perceived as the most sustainability-relevant course in the Nigerian engineering curriculum. Nearly all the listed courses were biased towards environmental issues, and no sustainability-titled course featured amongst the mentioned courses. The Nigerian engineering community expressed overwhelming support for sustainability in terms of the involvement of Nigerian engineers (88.4%), need for sustainability expertise (80.5%), and sustainability importance in engineering education (87.8%). On intervention approach, stakeholders viewed the suitability of the approaches in descending order thus: integration into core courses (63.6%), common courses (58.6%), new cross-disciplinary course (53.7%) and new discipline-specific course (52.7%). Four emergent themes from the general comments were approach, focus area, challenge and imperative.

Chapter Eight

8 Formulating an Intervention for Nigerian Engineering Curriculum

Introduction

This chapter formulates an intervention for the Nigerian engineering curriculum. A bipartite intervention featuring guidelines and an introductory course on sustainable engineering is presented. The intervention is proposed based on the findings in the preceding chapters (*Chapters Five* to *Seven*) as well as insights from the reviewed literature (*Chapters Two* and *Three*). The chapter proceeds with a delineation of the intervention requirements arising from the analysed data in the study. Thereafter, the details of the intervention are provided and the key elements of a proposed course are subsequently trialled by means of a sustainability workshop. The prospect of running a sustainable engineering course in a typical Nigerian engineering class setting is assessed. An overview of the workshop stating its layout including some preliminary sustainability assessments and a presentation on sustainable engineering is provided. Other features of the workshop highlighted in the chapter are sustainable engineering activity and post-workshop assessments. The chapter concludes with a discussion of the findings and limitations.

Defining Intervention Requirements

From the findings in the preceding chapters intervention requirements for the Nigerian engineering curriculum can be defined. What follows is a description of the elements of a proposed intervention covering strategy, method, approach, and means.

Strategy

Holistic – Congruent with findings of the present study and global best practice, a sustainability education intervention for the Nigerian engineering curriculum should be holistic. Holistic strategy here implies that the engineering curriculum, understood in its broad sense as a stakeholder-led process and involving all facets of an educational institution, should be targeted. Hence, all aspects of the Nigerian engineering curriculum should be imbued with sustainability concepts. Responsibility for fulfilling these requirements should be vested in educational authorities at different levels of command.

Method

Hybrid Method – The hybrid method of curricular development which combines top-down and bottom-up approaches is proposed. The top-down approach will cover sustainability education policy-making and inclusion of a sustainability course in the BMAS document. The bottom-up approach involves recommendations and sustainability course designs initiated from HEIs or independent researchers. With regard to the top-down sustainability education policy in Nigeria, the Nigerian FME and FMEnv will be key actors. Additionally, NUC and COREN will be responsible for benchmarking both sustainable engineering course and sustainability proficiency as minimum requirements for all engineering programmes and graduates.

Approach

Multidisciplinary – In terms of approach, multidisciplinarity is envisaged as the appropriate way to constitute a sustainability education intervention for Nigerian engineering curriculum. This requirement should be reflected in all sustainability efforts in HEIs including curricular development and course designs.

Means

Common/Elective Courses – The common/elective courses should be targeted for an initial integration of a sustainability course into the Nigerian engineering curriculum. Consequently, a sustainable engineering module should be designed and taught as a common engineering course in all the Nigerian HEIs. The sustainability course should subsume and replace the existing *Engineer in Society* module.

Guideline for Intervention

A guideline for sustainability education intervention in Nigerian engineering curriculum is presented in Figure 8.1. The diagrammatic representation is intended to convey all the aforementioned intervention requirements and elements. Accordingly, holism is reflected in the interconnectedness of the roles contained in individual boxes and in the intricate relationship between constituent elements. Each step or boxed element is linked to and influenced by a preceding and succeeding step. The bidirectional arrows or connectors are indicative of the hybrid method (top-down and bottom-up) defined in the intervention requirements. This implies that sustainability education intervention for the Nigerian engineering curriculum can be initiated at any level and advanced iteratively.

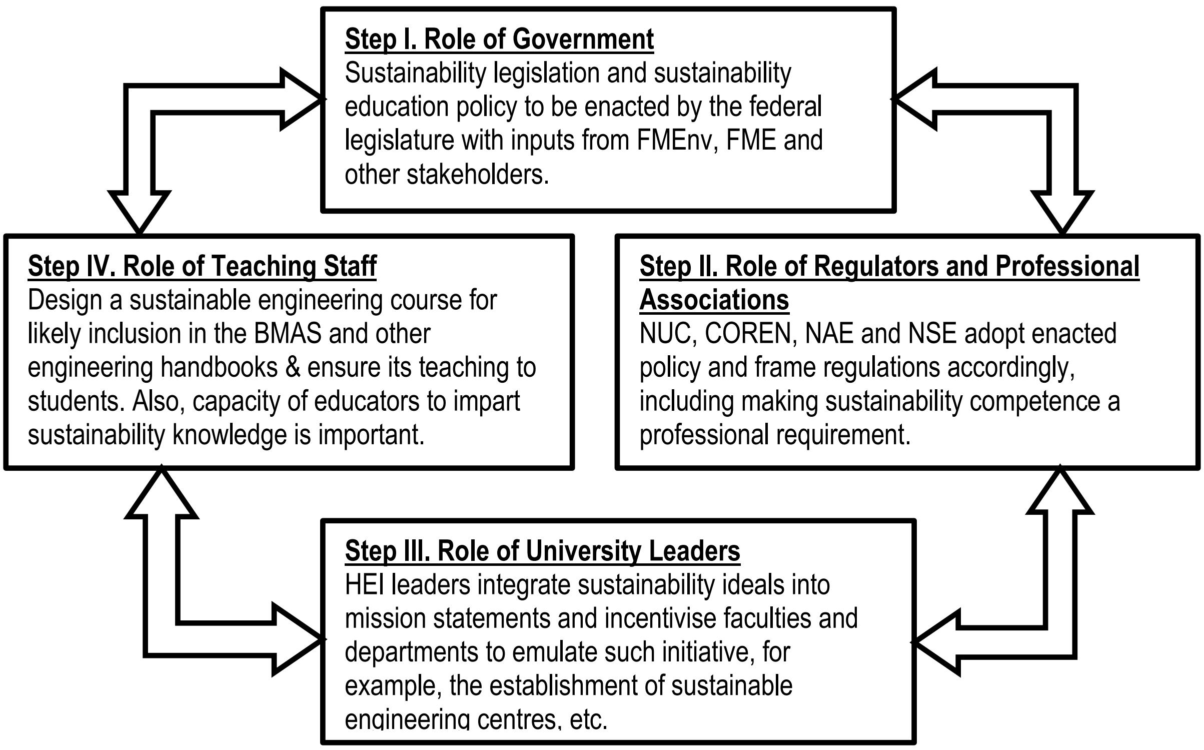


Figure 8.1. Guideline for intervention in Nigerian engineering curriculum

Role of Government

The Nigerian Government has a role to play in any sustainability education intervention for the country. A crucial governmental role could be the enactment of a sustainability legislation from which a sustainability education policy can be derived. The Federal Government through FMEnv and FME can originate an executive bill on sustainability education for legislation by the National Assembly. The enactment of a sustainability education policy will not only provide a legal framework for an intervention, but also incentivise stakeholders to gravitate towards sustainability efforts. Inputs for the executive bill could proceed bottom-up and top-down to facilitate broad participation. Furthermore, a stakeholder conference could be held to provide an avenue for such wide consultations. The existing OSSAP-SDGs and RCEs could be tasked to network with appropriate organisations to ensure an inclusive policy proposal.

Role of Regulators and Professional Associations

Regulators of engineering education and practice in Nigeria as well as engineering professional associations are important stakeholders in any sustainability intervention in Nigerian engineering curriculum. Sequel to a sustainability education policy, NUC, COREN, NAE and NSE could frame engineering practice and education regulations around sustainability ideals. NUC and COREN could insert in their episodically reviewed regulatory documents the requirement for sustainability proficiency amongst all engineering graduates. NSE and NAE could include the evidence of sustainability considerations in engineering practice or project as a prerequisite for membership. These suggested intervention tacks at the level of regulators and professional associations could be effective in enabling not only a sustainability education, but also sustainable engineering practice in Nigeria.

Role of University Leaders

Leadership in the context of sustainability education occupies a midpoint between positivism and naturalism. Whilst leadership from the positivist stance is considered to be inherently amoral, the naturalistic perspective concedes the intrinsic intertwinement between morality and leadership (Carey, 2002). Therefore, in a strict sense, naturalism and positivism diverge on the moral and logical questions of leadership. The University of Cambridge Institute for Sustainability Leadership defines a sustainability leader as “someone who inspires and supports action towards a better world” (Visser and Courtice, 2011, p.2). This is a morally laden statement in which the legitimacy of sustainability leadership is derived from the compelling need to address sustainability crises. The sustainability education construct established in *Chapter Two* adduces both logical and moral reasoning to justify the need for a sustainability leadership. This aligns with the contingency view of leadership, which is underpinned by pragmatism. Hence, the nature of university leadership suggested in the guideline is pragmatic.

The role of university leaders in a sustainability education intervention for Nigerian engineering curriculum is critical. The present intervention proposal targets the Nigerian HEIs, which are expected to imbue and teach sustainability themes in all engineering programmes. The university leadership at every level must participate in supporting this objective for an effective and meaningful outcome. One of the ways HEI leaders could contribute is by promoting sustainability ideals in university, faculty or departmental mission statements. This would provide some visibility to sustainability as a policy in the HEI and also serve as a reorientation tact. University leaders could similarly encourage the creation of sustainable engineering research groups and centres to further entrench sustainability issues in the HEIs. Ultimately, university leaders must be predisposed towards fostering engineering sustainability initiatives for a meaningful intervention.

Role of Teaching Staff

Teaching staff are typically tasked with the responsibility of imparting knowledge to students. In the case of sustainability education intervention for Nigerian engineering programmes, the role of the teaching staff is significant. The teaching staff could be tasked with the design of a sustainability course in line with a nationally recognised minimum standard. However, the teaching staff must have the intellectual capacity and proficiency to teach sustainable engineering courses in the HEIs. Based on the findings in the present study (*Chapter Five*), the educators may have to be capacitated through instruction in engineering sustainability. Hence, part of the intervention should focus on educating engineering educators about sustainable engineering.

Course Design

An introductory course on sustainable engineering could be designed for the Nigerian engineering curriculum in the light of the defined intervention requirements and guideline. The course could be entitled *An Introduction to Sustainable Engineering in* Nigeria. Such a course should contain the wide-ranging issues highlighted in the present study including contextual sustainability matters and the universality of the sustainability challenge. Being an introductory course, the module should establish the imperative, raison d'etre, and the rationale for sustainable engineering as well as the application and relevance of engineering sustainability in Nigeria. Some elements of PBL and PjBL such as seminars, class activities, scenarios and collaborative projects should be incorporated in the course structure. Furthermore, the course should feature such other teaching techniques as lecturing and case study where appropriate. Both individual and group projects should feature in the course.

In addition, expected learning outcomes, assessment format and weekly topics should be explicitly stated in the course outline. The learning outcomes should be couched in terms of observable abilities and traits. Examples of topics that could feature in the course are *Origins of Sustainable Engineering*, *Systems Thinking, and The Engineer as a Leader*. Others are *Sustainable Engineering in Nigeria*, *Application of Sustainable Engineering* and *Earth Systems Engineering and Management.* The course could fit into the common/elective courses of the Nigerian engineering curriculum. It should aptly subsume and replace the ubiquitous *Engineer in Society* course whose existing content can be covered under the *Sustainable Engineering in Nigeria* topic. The sustainable engineering course designed for the Nigerian engineering curriculum could be included in the official BMAS document and subsequently in the engineering handbooks of Nigerian HEIs. The course outline for the proposed module is presented below.

***Course Title**: An Introduction to Sustainable Engineering in Nigeria*

***Introduction:** Sustainability is a 21st century challenge that has elicited political, ethical and intellectual debates. Some of the crises that cued sustainability advocacy such as biodiversity loss, climate change, carbon emissions and hyper-consumerism have been attributed to engineering. Being the lifeblood of socioeconomic progress, engineering is expected to align with sustainability ideals for the benefit of present and future generations. To this end, sustainable engineering offers a conceptual departure from conventional engineering by broadening the problem and solution domains of engineering across the sustainability pillars of economy, society and environment. Globally, sustainable engineering principles are shaping engineering practice and Nigerian engineers are expected to imbibe such values in order to contribute towards addressing sustainability challenges. This course aims to introduce engineering students to the fundamentals of sustainable engineering.*

***Learning Outcomes**: At the end of the course, students should be able to:*

(1) Appreciate the origins, definitions and rationale of sustainable engineering.

(2) Identify and explain the underlying philosophies, frameworks, principles and tools of sustainable engineering.

(3) Identify and explain the sustainability implications of engineering projects and activities in Nigeria.

(4) Learn to communicate in short essay form and student-led seminars.

***Assessment**: Seminar participation/presentation (10%); Sustainable Engineering Activity (15%); 1000 word discussion paper (25%); 2000 word essay (50%)*

***Week 1** – Origins of Sustainable Engineering: The evolution of sustainable engineering via precursory activisms such as conservationism, environmentalism, etc., highlighting the contributions of key 1960s environmentalists including Rachel Carson, Murray Bookchin, etc. Role of UN World Commission on Environment and Development (UNWCED), the Brundtland Report of 1987 and ratification of global sustainability pacts. A discussion of the rise of contemporary sustainable engineering ideas will feature.*

Week 2 *– Defining Sustainable Engineering: Various attempts at a definition of sustainable engineering will be presented. Pillars of sustainability including economy, environment, and society that inform all extant sustainable engineering definitions will feature. Conventional engineering is differentiated from sustainable engineering. The underlying philosophies of sustainable engineering, such as anthropocentrism, ecocentrism, egalitarianism, complexity, holism, precautionary principle and technocentrism are addressed.*

Week 3 *– Rationale for Sustainable Engineering: The question of why sustainable engineering is needed will be treated. Some important reasons such as the intricate connection between economic development and engineering as well as the instrumental value of engineering are covered. The need to address myriad social and ecological crises across the globe is stressed. Examples are given in the global, continental, regional and national contexts.*

Week 4 *– Systems Thinking: Applying systems notions to problem-solving endeavours dubbed systems approach with system thinking as a key cognitive tool. System thinking as a way of thinking or engaging with the world based on the systemic perspective is differentiated from reductionism and mechanism. A brief history of systems thinking including incipient ideas in systems theory will be addressed. Several applications of systems thinking in sustainable engineering are presented.*

Week 5 *– Sustainable Engineering Framework: Frameworks have been copiously proposed in the literature. Predicated on the concept of sustainable development, the frameworks generally embody principles and tools derived eclectically from several disciplines. Examples include Earth Charter Principles, Eco-Industrial Parks (EIPs), Design for X (DfX), LCA, etc. The integration of these components is usually presented as a sustainable engineering framework.*

Week 6 *– Application of Sustainable Engineering: Sustainable engineering is gaining currency both as a profession and as a discipline. There is so much enthusiasm about applying the ideals of the discipline to real-life projects. Numerous examples of projects in which the principles of sustainable engineering are applied will be presented.*

Week 7 *– Sustainable Engineering in Nigeria: An overview of engineering in Nigeria is given followed by a review of the Nigerian sustainability experience. Topics covered in Engineer in Society are subsumed here. Nigerian engineering code of ethics and sustainability principles are compared. The role of COREN in engineering sustainability is discussed. The challenges of sustainable engineering in Nigeria as well as mitigation measures are covered.*

Week 8 *– Sustainable Engineering Activity: An engineering project (proposed, ongoing or completed) in the Nigerian context is chosen. Students are tasked to identify the sustainability implications of the selected project and thereafter suggest possible mitigations. Implications should cover the sustainability pillars of economy, environment and society. A 1000 word report is written at the end of the activity.*

Week 9 – *Sustainable Engineering Seminar I: Various literature on sustainable engineering is provided for students to critically review and subsequently present a critique of a selected work during short student-led seminars. Students are expected to write a 1000 word discussion paper on the selected piece of literature.*

Week 10 *– Earth Systems Engineering and Management (Allenby, 2012): Sustainable Engineering at a Planetary Scale. Although still a maturing field, sustainable engineering at the ESEM level can draw on a number of areas of study. Assorted ideas on geoengineering, urban design management & high modernism, theoretical ESEM principles, ESEM governance principle and final principle will be addressed.*

Week 11 *– Sustainable Engineering Seminar II: Various media sources other than textbooks and journals on sustainability are suggested for students to critically review and subsequently make a presentation during short student-led seminars. Students will write a 1000 word discussion paper on the selected medium.*

Week 12 *– The Engineer as Leader (Allenby, 2012): In the sustainability worldview, an engineer should exhibit myriad qualities: commitment, respect for values and opposing viewpoints, willingness to learn and work in multidisciplinary contexts. Engineers are increasingly required to also function as leaders within their institutions, communities, and society. An engineer should have ideas about a variety of topics.*

***Weeks 13** – **15** – Collaborative Sustainable Engineering Project: Working in a team, students collaborate to conceive and design a project in accord with sustainability ideals. An ideal collaborative project is multidisciplinary and should involve students of various engineering disciplines. A 2000 word essay is written individually in addition to a 5000 word collaborative project report.*

Reading List:

1. *Allenby BR. (2012) The Theory and Practice of Sustainable Engineering, Pearson Education Publishers*
2. *Bell S. (2011) Engineers, Society, and Sustainability, Morgan and ClayPool Publishers*
3. *Roberts M. (2014) Sustainability Principles and Practice, Routledge Publishers*
4. *Jonker G. and Harmsen J. (2012) Engineering for Sustainability: A Practical Guide for Sustainable Design, Elsevier Publishers*
5. *Azapagic A. and Perdan S. eds. (2011) Sustainable Development in Practice: Case Studies for Engineers and Scientists, John Wiley & Sons Publishers*

***Note**: Each Week = 2 h*

Trialling a Sustainable Engineering Course

This section trials a sustainable engineering course by means of a sustainability workshop. The prospect of running a sustainable engineering course in a typical Nigerian engineering class setting is assessed. Participants (n=21) in the workshop were recruited randomly and included undergraduate (n=11) and postgraduate (n=10) students. The workshop held separately for the two student groups. The section presents an overview of the workshop stating its layout including preliminary sustainability assessments and a presentation on sustainable engineering. Other features of the workshop highlighted are sustainable engineering activity and post-workshop assessments.

Workshop Overview

A workshop was organised to trial an introductory course on sustainability in a typical Nigerian engineering class setting. The workshop entitled *Sustainable Engineering Workshop* (Figure 8.2) involved two groups of students: undergraduates (n=11) and postgraduates (n=10). The students were recruited via a handbill (Figure 8.3) distributed randomly at two Nigerian engineering institutions in Kaduna metropolis. The workshop was conducted separately for each student category. Both the undergraduate and postgraduate sessions held at different times in the Air Force Institute of Technology, Kaduna. Whilst the undergraduate session held on 1 July 2017, the postgraduate session took place on 8 July 2017. The handbill distributed for the workshop contained information on the purpose of the workshop, dates of sessions, venue and contact address.

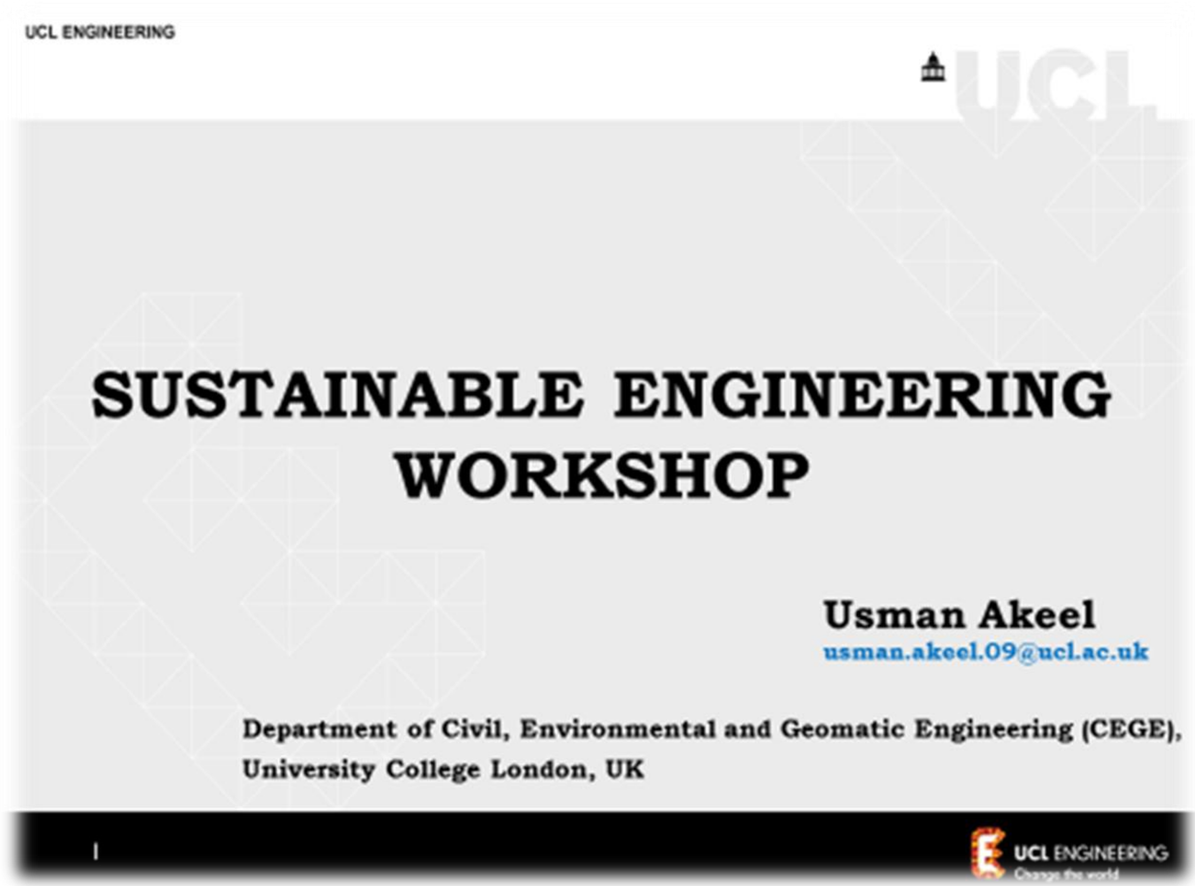


Figure 8.2. Sustainable engineering workshop first slide

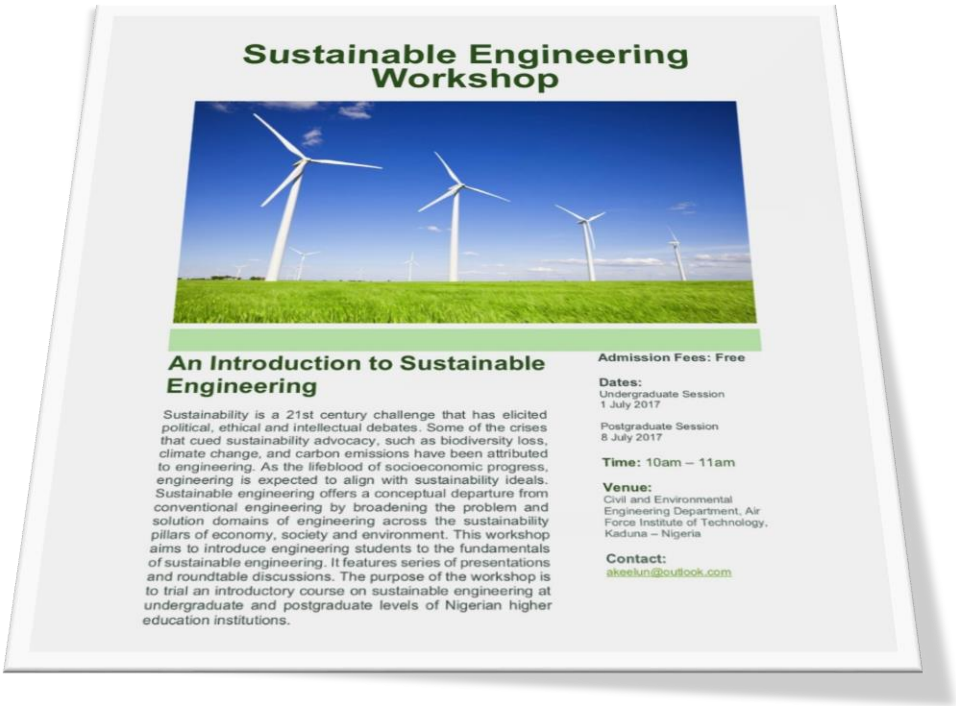


Figure 8.3. Sustainable engineering workshop leaflet

Layout

The layout of the workshop is presented in Figure 8.4. Four sessions were conducted in the sustainable engineering workshop over a one-hour period including preliminary assessments, sustainable engineering presentation, sustainable engineering activity, and post-workshop assessments.

Session 1: Preliminary Assessments

Session one lasted 10 min and focused on evaluating the sustainability knowledge of the participating students prior to the presentation on sustainable engineering. The session proceeded with students undertaking a five-question quiz covering basic aspects of sustainability and sustainable engineering. These included open-ended questions on the definition of sustainability, pillars of sustainability, and definition of sustainable engineering. Others covered the rationale for sustainable engineering and examples of projects that can be engineered sustainably. A sample of the pre-workshop sustainability test is at Appendix XII.

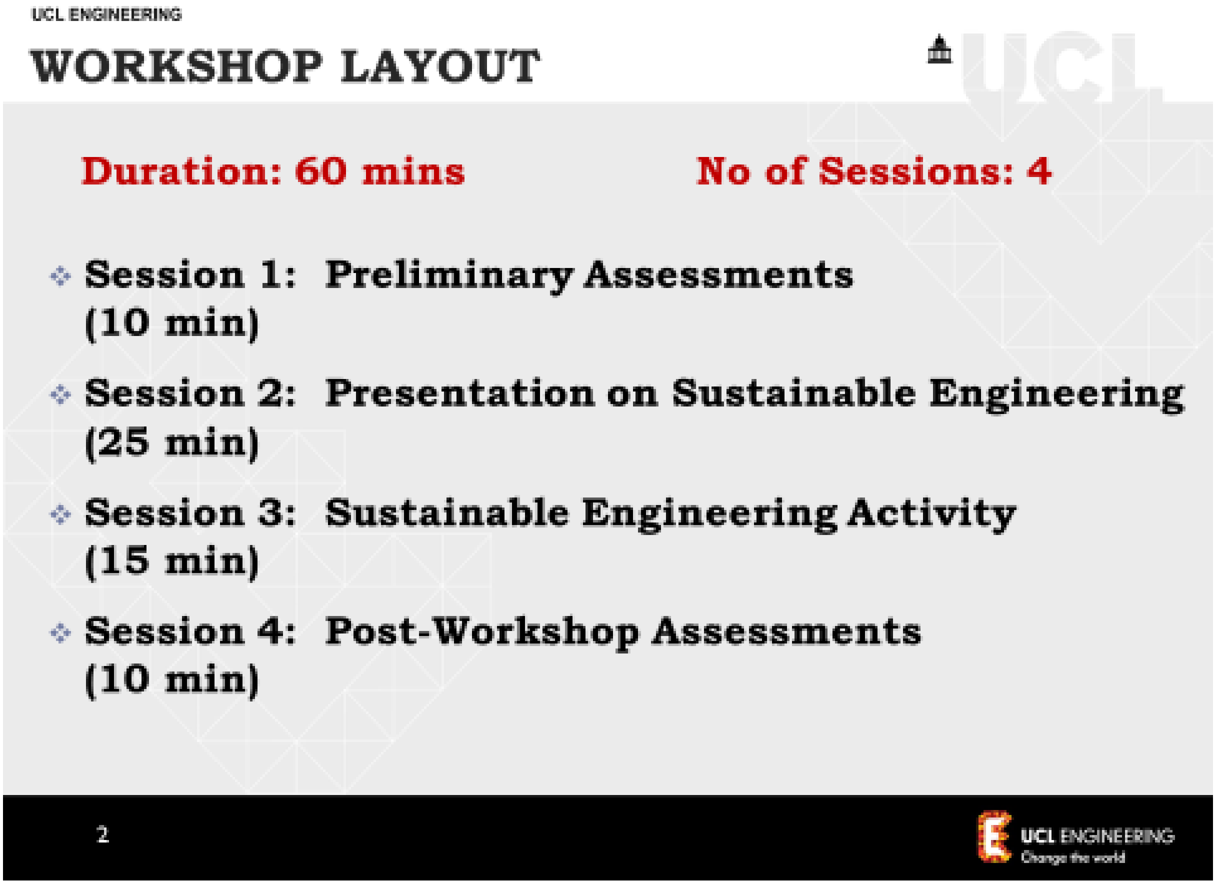


Figure 8.4. Sustainable engineering workshop layout

Session 2: Presentation on Sustainable Engineering

Session 2 lasted 25 min and featured a presentation on sustainable engineering. The presentation discussed such topics as origins of sustainable engineering, definition of sustainable engineering, rationale for sustainable engineering, frameworks, tools and principles of sustainable engineering, and application of sustainable engineering. The presentation was a concise summary of the Weeks 1 – 3 & 5 – 6 topics in the designed introductory sustainable engineering course (see *Chapter Nine*). Students were exposed to the precursory activisms, movements, and global commissions that contributed to the evolution of sustainable engineering. The various connotations and renditions of sustainability and sustainable engineering as well as the pillars of sustainable development were explained to the students. Significantly, conventional engineering was differentiated from sustainable engineering in order to aid students' appreciation of the distinction between the two problem-solving approaches.

The field of sustainable engineering was rationalised based on the intricate link between engineering and economic activities. Students were made to appreciate that engineering, being the principal facilitator of socioeconomic activities, is required for societal progress such as promoted in sustainability discourse. The instrumental value of engineering was invoked with reference to historic engineering interventions in society to underline the point that sustainability challenges can also benefit from engineering solutions. Examples of sustainable engineering frameworks derived from the various tools and principles highlighted in *Chapter Three* were mentioned in the presentation. Handouts on the sustainable engineering principles were given to the students as further reading materials. In highlighting the application of sustainable engineering, the examples of revamping Nigerian refineries and the completed Jubilee River in England were offered. Whilst the latter exemplified a project that was executed in line with the principles of sustainable engineering, the former epitomised a project that can be engineered sustainably. The presentation ended with a summary of the major points.

Session 3: Sustainable Engineering Activity

Session 3 featured a sustainable engineering activity which lasted 15 min. The activity presented the students with a railway project scenario in Nigeria and tasked them to consider its possible sustainability issues. The task read thus:

"*In order to expand intra-national transportation, Nigeria has begun to revamp its railway system. The Abuja-Kaduna rail project is already up and running. Imagine you were an engineer on the project. Using the 3 pillars of sustainability (environment, society and economy), what sustainability issues would you consider in the project?*"

This activity was designed to be an interactive session with the students sharing ideas and experiences amongst themselves. Examples under each sustainability pillar were provided in order to assist the students in coming up with relevant issues. Students were encouraged to think of possible mitigations of the concerns raised. The Abuja-Kaduna railway project was chosen for the reason of familiarity. As residents of Kaduna metropolis, the students might be aware of the railway project and some might have journeyed on the train. Such personal experience with the project could perhaps aid the students' appreciation of sustainability issues.

Session 4: Post-Workshop Assessments

Session 4 which lasted for 10 min featured two assessments, namely post-workshop sustainability test and workshop evaluation. The post-workshop sustainability test was a repeat of the quiz undertaken by the students at the beginning of the workshop. The students were asked the same five open-ended sustainability questions contained in the pre-workshop test. There was, however, a slight variation in the questioning style as seen in the quiz sample at Appendix XIII. The aim of the post-workshop test was to assess the sustainability learning that had taken place as a result of the students' participation in the workshop. The outcome of the test would be compared with that of the pre-workshop sustainability test, hence the need to replicate the questions. The students were advised to answer the questions in their own words and avoid verbatim reproduction of definitions, except for key terms.

For the workshop evaluation, a survey was administered to the students featuring four questions. Students were requested to reflect on the workshop and respond to the following statements indicating the extent of agreement or disagreement with them: (a) Participating in the workshop helped me learn about sustainability concepts (b) Participating in the workshop helped me appreciate the need for sustainable engineering in Nigeria (c) I enjoyed participating in the workshop (d) I am convinced that sustainable engineering education should be introduced into Nigerian engineering curriculum. The workshop evaluation survey intended to assess students' satisfaction with the sustainable engineering workshop, which would be useful in appreciating the prospect of success of the introductory sustainable engineering course. A sample of the workshop evaluation survey is at Appendix XIV.

Test Scoring Criteria

The pre- and post-workshop tests were allotted a maximum possible score of 20 each. The test questions, Q1- Q5, were assigned highest possible scores of 5, 3, 5, 4 and 3 respectively based on importance and complexity. Two markers who possessed a graduate-level sustainability knowledge assessed the tests with each quiz marked twice and the mean calculated. The use of key terms in responding to the definition questions was considered essential for a pass mark on those questions. The questions that required a list of items such as pillars of sustainability and examples of sustainable engineering projects were passed only when the items were accurately mentioned.

Hence, participants could score zero marks on such questions. With regard to the sustainable engineering justification question, a zero mark was possible where respondents failed to logically rationalise the field of engineering sustainability. Citing relevant examples attracted full marks on the justification question.

Pre-Workshop Sustainability Test

The sustainability knowledge of the participating students (n=21) was tested before the workshop. Results of the test are presented below.

Undergraduate Participants

Undergraduate students (n=11) were tested on five sustainability-related questions. The quiz covered the definition of sustainability, sustainability pillars, definition of sustainable engineering, justification of sustainable engineering, and examples of sustainable engineering projects. Table 8.1 presents the result of the pre-workshop test. On the question of sustainability definition, the average score was 2.1 out of 5 with only 2 students scoring up to 4 marks. The average score on the pillars of sustainability was 0.9 out of 3, which implied that only few students acknowledged the sustainability pillars. Students had an average score of 1.5 out of 5 on the sustainable engineering definition question, with some of the students unable to even attempt a definition. Asked to justify the field of sustainable engineering, students earned a mean score of 0.7 out of 4 and nearly half of them failed to rationalise the discipline. On the question of projects that can be engineered sustainably, students obtained an average score of 1.9 out of a maximum of 3, with only three of them providing relevant examples. Overall, the mean score of the undergraduate students on the pre-workshop sustainability test was 7.2 out of a maximum score of 20.

Table 8.1. Undergraduates pre-workshop sustainability test scores

Student (n = 11)	Sustainable development definition **Max score: 5**	Sustainable development pillars **Max score: 3**	Sustainable engineering definition **Max score: 5**	Sustainable engineering justification **Max score: 4**	Sustainable engineering projects **Max score: 3**	**Total** **Max score: 20**
AL	1	1	0	0	2	4
AS	2	0	1	0	3	6
AY	3	1	0	0	1	5
BR	2	0	0	0	0	2
IS	4	1	1	0	1	7
MH	1	0	2	1	2	6
NJ	4	3	5	2	2	16
NS	0	0	1	1	3	5
SG	3	3	4	2	2	14
SL	1	1	2	1	2	7
UR	2	0	1	1	3	7
Mean	**2.1**	**0.9**	**1.5**	**0.7**	**1.9**	**7.2**

Postgraduate Participants

The pre-workshop test administered to the postgraduate students (n=10) featured questions on sustainability definition, sustainability pillars, sustainable engineering definition, sustainable engineering rationale, and examples of sustainable engineering projects. Table 8.2 presents the scores of the postgraduate students on the pre-workshop sustainability test. On the question of sustainability definition, the average score was 1.8 out of a maximum score of 5. Many students could not define sustainability. None of the postgraduate students was able to mention the pillars of sustainability which returned an average score of 0.0 on the question. Students had a mean score of 1.7 out of 5 on the question of the definition of sustainable engineering with two students failing to attempt the question. The question on the justification of sustainable engineering recorded an average score of 1.1 out of a maximum of 4 points with nearly half of the students unable to justify the field. Asked to mention three examples of projects that can be engineered sustainably, almost all the postgraduate students cited relevant projects, with only one students unable to mention any. On the whole, the mean score of the postgraduate students on the pre-workshop sustainability test was 7.3 out of a maximum score of 20.

Table 8.2. Postgraduates pre-workshop sustainability test scores

Student (n = 10)	Sustainable development definition **Max score: 5**	Sustainable development pillars **Max score: 3**	Sustainable engineering definition **Max score: 5**	Sustainable engineering justification **Max score: 4**	Sustainable engineering projects **Max score: 3**	**Total** **Max score: 20**
AB	2	0	0	0	3	5
AM	1	0	0	0	3	4
BK	2	0	1	0	0	3
BS	2	0	2	1	3	8
GD	3	0	2	3	3	11
GR	2	0	3	2	3	10
KG	2	0	3	2	3	10
NT	3	0	4	1	3	11
OD	0	0	1	2	3	6
VN	1	0	1	0	3	5
Mean	**1.8**	**0.0**	**1.7**	**1.1**	**2.7**	**7.3**

Sustainable Engineering Activity

A sustainable engineering activity was undertaken during the workshop. Excerpts from the activity are presented below.

Undergraduate Participants

Table 8.3 presents excerpts from undergraduate student responses. The students generally evinced an understanding of the issues raising environmental sustainability concerns such as biodiversity loss, air pollution, vibration effects, deforestation and possible ground water pollution. The recurring social sustainability issues included security, safety, and disruption of settlements, whilst economic considerations were mostly construction, maintenance, and training costs as well as financial implications of extenuating both social and environmental sustainability concerns.

Table 8.3. Excerpts from sustainable engineering activity - undergraduates

<table>
<tr><td colspan="3">Task: In order to expand intra-national transportation, Nigeria has begun to revamp its railway system. The Abuja-Kaduna rail project is already up and running. Imagine you were an engineer on the project. Using the 3 pillars of sustainability (environment, society and economy), what sustainability issues would you consider in the project?</td></tr>
<tr><th>Environmental Issues</th><th>Social Issues</th><th>Economic Issues</th></tr>
<tr><td>Example: Biodiversity loss resulting from felling trees and land clearing for rail tracks, etc.</td><td>Example: Disruption of settled communities vicinal to railway paths</td><td>Example: Economic cost of addressing environmental sustainability issues</td></tr>
<tr><td colspan="3">Excerpts from student responses</td></tr>
<tr><td>Effects on underground mineral resources [AL]

Mechanical disturbance to the environment [AS]

Air pollution [AY]

Due to biodiversity loss of felling trees, you need to replant another trees after the work has been completed [BR]

Emission of toxic gases from the train [MH]

Disruption of dwelling resulting from vibration that affect the performance of all nearby buildings, especially where the rail tracks pass through rural areas [NS]

Might lead to pollution of water [SG]

Deforestation which may cause erosion in such a community [SL]</td><td>Cause much more delay when there is a fault [AL]

Security [AS]

Safety precautions where the railway crosses through roads and small towns or villages [BS]

Due to accident the people will not properly agree [BR]

Possibility of insecurity occurrence [IS]

Could lead to death of children while crossing the tracks unknowingly/playing [MH]

It takes a little time before people agree to come to terms with the idea of transporting in trains [NJ]

Delay of transported goods especially very perishable goods such as vegetable and fruits can be affected compared to highway transportation [NS]

Less cost of transportation may lead to increased social visits and activities [SL]</td><td>Heavy plants are to be used during the construction which also cost much economically [AL]

Maintenance cost [AS]

Cost of relocation of affected community [MH]

Nigeria doesn't manufacture trains, so we have to invite China or other developed country to employ their expertise and technical knowhow which in turn cost money [NJ]

Issue of inadequate professionals to render the system more effective [NS]

Cost of moving large train tracks and construction plants [SL]

Cost of controlling carbon monoxide, sound and vibration [UM]</td></tr>
</table>

Postgraduate Participants

Table 8.4 presents excerpts from postgraduate student responses to the sustainable engineering task. The students generally demonstrated an understanding of the issues with considerations for the environment eliciting such concerns as noise pollution, reduced farmland, soil nutrient loss, and air pollution. In terms of social sustainability, the students cited security, reduced rural-urban migration, safety, and severance of familial ties. The economic concerns included material costs, maintenance, revenue, cheaper fares, and improved economic activities.

Table 8.4. Excerpts from sustainable engineering activity - postgraduates

Task: *In order to expand intra-national transportation, Nigeria has begun to revamp its railway system. The Abuja-Kaduna rail project is already up and running. Imagine you were an engineer on the project. Using the 3 pillars of sustainability (environment, society and economy), what sustainability issues would you consider in the project?*		
Environmental Issues	**Social Issues**	**Economic Issues**
Example: Biodiversity loss resulting from felling trees and land clearing for rail tracks, etc.	**Example**: Disruption of settled communities vicinal to railway paths	**Example**: Economic cost of addressing environmental sustainability issues
Excerpts from student responses		
Decrease in farmland area [AB] *Reduction in grazing areas for livestock [BK]* *Poor disposal procedure of trees fell could lead to pollution [GD]* *Building of new houses for the inhabitant will cost, claiming more land for the project [GR]* *Noise pollution [KG]* *Air pollution [NT]* *Vibrations of trains moving on their tracks will have negative impact on ecology close to the track [VN]* *Evaporation of moisture nutrient of soil due to exposure to sunlight [GD]* *Carbon pollution and adverse effect on soil substructure [NT]*	*Provision of security for communities along railway paths [AM]* *The advent of railway lines would reduce rural to urban migration. This is because an individual can work in a city while residing in his/her village [BK]* *Safety precautions where the railway crosses through roads and small towns or villages [BS]* *Loss of family ties as a result of displacement of communities [KG]* *May change the social behaviours of the inhabitants along the tracks, i.e. change of primary occupation [NT]* *Reduced kidnapping incidents between the cities of Abuja and Kaduna [OD]*	*Economic cost of materials [AM]* *Increase in rate of transmission of goods/services hence reduction in cost of goods [BK]* *The cost of maintenance of the rail tracks and the train as well [BS]* *Trees fell can be used for commercial purpose [GD]* *The government budget will be increased [GR]* *Increase in revenue for government [KG]* *Cost of relocating the settlements disrupted [NT]* *Improved economic activities between the city of Kaduna and Abuja [OD]* *Cheaper means of transportation [VN]*

Post-Workshop Sustainability Test

The sustainability knowledge of the participating students (n=21) was tested after the workshop. Results of the test are presented below.

Undergraduate Participants

Undergraduate students (n=11) were tested on five sustainability-related questions at the end of the workshop. This was merely a repeat of the pre-workshop test questions featuring sustainability definition, pillars of sustainability, definition of sustainable engineering, justification of sustainable engineering, and examples of sustainable engineering projects. Table 8.5 presents the result of the post-workshop test. The sustainability definition question recorded an average score of 2.4 out of 5 with one student unable to define the concept. The average score on the sustainability pillars was 3.0 out of 3, which implied that all the students correctly identified the pillars. Students had an average score of 3.4 out of a maximum score of 5 on the sustainable engineering definition question, with a few students still struggling with the definition. On the question of the rationale for sustainable engineering, students scored a mean of 2.0 out of 4, with a few of them unable to justify the field. Regarding the projects that can be engineered sustainably, students had an average score of 2.7 with one student failing to provide at least three appropriate examples. The average score of the undergraduate students on the post-workshop test was 13.5 out of 20.

Table 8.5. Undergraduates post-workshop sustainability test scores

Student ID (n = 11)	Sustainable development definition **Max score: 5**	Sustainable development pillars **Max score: 3**	Sustainable engineering definition **Max score: 5**	Sustainable engineering justification **Max score: 4**	Sustainable engineering projects **Max score: 3**	**Total** **Max score: 20**
AL	2	3	3	2	3	13
AS	2	3	3	1	3	12
AY	1	3	5	0	1	10
BR	2	3	1	1	3	10
IS	5	3	4	2	3	17
MH	1	3	2	2	3	11
NJ	4	3	5	3	2	17
NS	3	3	4	3	3	16
SG	3	3	4	3	3	16
SL	3	3	2	2	3	13
UR	0	3	4	3	3	13
Mean	**2.4**	**3.0**	**3.4**	**2.0**	**2.7**	**13.5**

Postgraduate Participants

The post-workshop test administered to the postgraduate students (n=10) featured questions on sustainability definition, sustainability pillars, sustainable engineering definition, sustainable engineering rationale, and examples of sustainable engineering projects. Table 8.6 presents the result of the post-workshop sustainability test. An average score of 2.8 out of a maximum of 5 was recorded on the question of sustainability definition. Only one student could not define sustainability. All the students were able to mention the pillars of sustainability which returned an average score of 3.0 on the question. Students had a mean score of 3.4 out of 5 on the question of the definition of sustainable engineering, with all the participants fairly attempting the question. The question on the justification of sustainable engineering recorded an average score of 2.0 out of a maximum of 4 points with two students unable to justify the field. Asked to mention three examples of projects that can be engineered sustainably, all the postgraduate students cited relevant projects. Overall, the mean score of the postgraduate students on the post-workshop sustainability test was 14.2 out of a maximum score of 20.

Table 8.6. Postgraduates post-workshop sustainability test scores

Student ID (n = 10)	Sustainable development definition **Max score: 5**	Sustainable development pillars **Max score: 3**	Sustainable engineering definition **Max score: 5**	Sustainable engineering justification **Max score: 4**	Sustainable engineering projects **Max score: 3**	**Total** **Max score: 20**
AB	3	3	3	1	3	13
AM	3	3	3	2	3	14
BK	2	3	2	0	3	10
BS	4	3	5	3	3	18
GD	3	3	3	3	3	15
GR	0	3	3	2	3	11
KG	2	3	4	3	3	15
NT	4	3	5	3	3	18
OD	2	3	2	0	3	10
VN	5	3	4	3	3	18
Mean	**2.8**	**3.0**	**3.4**	**2.0**	**3.0**	**14.2**

Collating Pre- and Post-Workshop Test Scores

Results of the pre- and post-workshop tests on the sustainability knowledge of the participating students were collated. The outcome of this comparison is presented in the succeeding sections.

Undergraduate Participants

Results (Table 8.7) showed that the performance of the undergraduate participants on the post-workshop test (M = 13.5, SD = 2.6) was better than the students' performance on the pre-workshop test (M = 7.2, SD = 4.1). All the students made remarkable progress in their overall scores on the sustainability test, although two students increased by less than 3 points. The mean increment between the pre- and post-workshop test scores was 6.3 with a standard deviation of 3.1. A repeated-measures t-test found this difference to be statistically significant, $t(10) = 6.71$, $p < 0.001$. Hence, undergraduate students' appreciation of sustainability increased in the course of the sustainable engineering workshop.

Table 8.7. Summary of undergraduates pre- and post-workshop test scores

Student (n=11)	**Pre-Workshop** Max score:20	**Post-Workshop** Max score:20	**Difference**	**% Increase**
AL	4	13	9	225
AS	6	12	6	100
AY	5	10	5	100
BR	2	10	8	400
IS	7	17	10	143
MH	6	11	5	83
NJ	16	17	1	6
NS	5	16	11	220
SG	14	16	2	14
SL	7	13	6	86
UR	7	13	6	86
Mean	**7.2**	**13.5**	**6.3**	88
SD	**4.1**	**2.6**	**3.1**	**-**

Postgraduate Participants

Results (Table 8.8) showed that the performance of the postgraduate participants on the post-workshop test (M = 14.2, SD = 3.1) was better than the students' performance on the pre-workshop test (M = 7.3, SD = 3.0). All the postgraduate students improved their scores on the sustainability test with one student having a one-point increment. The mean difference between the pre- and post-workshop sustainability test was 6.4 with a standard deviation of 3.5. A repeated-measures t-test found this difference to be statistically significant, $t(9) = 6.16$, $p < 0.001$. Therefore, postgraduate students' appreciation of sustainability increased in the course of the sustainable engineering workshop.

Table 8.8. Summary of postgraduates pre- and post-workshop test scores

Student (n=10)	**Pre-Workshop** Max score:20	**Post-Workshop** Max score:20	**Difference**	**% Increase**
AB	5	13	8	160
AM	4	14	10	250
BK	3	10	7	233
BS	8	18	10	125
GD	11	15	4	36
GR	10	11	1	10
KG	10	15	5	50
NT	11	18	7	64
OD	6	10	4	67
VN	5	18	8	160
Mean	**7.3**	**14.2**	**6.4**	88
SD	**3.0**	**3.1**	**3.5**	**-**

Workshop Evaluation Survey

Undergraduate and postgraduate students were asked to reflect on the sustainable engineering workshop and indicate the extent of their agreement or disagreement with four statements. The first two statements sought students' opinion on the effectiveness of the workshop in facilitating a knowledge of sustainability concepts and in justifying the need for sustainable engineering in Nigeria. The last two statements were queries on whether participants enjoyed the workshop and if the workshop influenced their conviction for sustainability education to be introduced in the Nigerian engineering curriculum. The results of the workshop evaluation survey are presented in Table 8.9. From the findings, all the students positively agreed with the four statements. Hence, both undergraduate and postgraduate students opined that the workshop had helped them learn about sustainability. Similarly, the students agreed that the workshop was effective in helping them appreciate the need for sustainable engineering in Nigeria. Furthermore, both groups of students found the workshop enjoyable. Finally, the students unanimously accepted that sustainability education should be introduced in the Nigerian engineering curriculum Overall, the workshop evaluation revealed a positive feedback for an introductory sustainable engineering course.

Table 8.9. Result of workshop evaluation survey

***Survey prompt**: Reflecting on the sustainable engineering workshop you just completed, determine the extent to which you disagree or agree with the following statements:*	**Undergraduate (n=11)**		**Postgraduate (n=10)**		**Total (n=21)**
	Agree	Strongly agree	Agree	Strongly agree	
Participating in the workshop helped me learn about sustainability concepts	6	5	3	7	21
Participating in the workshop helped me appreciate the need for sustainable engineering in Nigeria	6	5	3	7	21
I enjoyed participating in the workshop	4	7	5	5	21
I am convinced that sustainable engineering education should be introduced into the Nigerian engineering curriculum	4	7	5	5	21

Discussion

A bipartite sustainability education intervention is proposed in this study. One part of the intervention sets out a guideline for the introduction of sustainability education in the Nigerian engineering curriculum. The other intervention element is a sustainability-titled introductory course designed to be included in the official BMAS document for subsequent adoption by the Nigerian HEIs.

Guideline for the Intervention

The intervention guideline is a set of steps that can be followed to ensure a successful implementation of sustainability education in the Nigerian engineering curriculum. An important feature of the guideline is that it espouses the top-down and bottom-up approaches as well as iteration. The four areas covered in the guideline, namely governmental role, regulatory and professional bodies, university leadership, and teaching staff are essential to the success of the intervention. Roles of government, regulators and university leadership in the implementation of a national sustainability education framework are greatly acknowledged in sustainability education research (UNEP-MESA, 2009; UNESCO, 2013). Additionally, the sustainability education declarations reviewed in *Chapter Two* repeatedly stress the critical role of educational authorities in the design and development of sustainability education. The Abuja Declaration, for example, assigns roles for HEIs, national and regional governments as well as development partners in its call for action on sustainability education in African HEIs (AAU, 2009). In the Nigerian context where the government has enormous powers to determine national interests, a fact also alluded to in the stakeholders’ comments (*Chapter Seven*), government involvement in sustainability education efforts cannot be overemphasised. This understanding has contributed to the composition of the guideline in which the Nigerian Government is allotted a noticeable role.

The rationale for including regulators and professional associations in the guideline is evident in their statutory roles. Studies have shown that the efforts of regulatory and professional associations cannot be decoupled from the modest progress made in sustainability education in engineering programmes of several countries (Coral, 2009; Penlington and Steiner, 2010). The experiences of UK-SPEC, ABET, and IPE are exemplary (*Chapter Two*). As already established in *Chapter Three*, COREN features a sustainability competence as a learning outcome of engineering programmes in Nigeria, but fails to follow through with an appropriate sustainability content in the BMAS document. Furthermore, the body has not made sustainability teaching an accreditation requirement as obtainable in the other regulatory bodies. Thus, in line with ideas of global best practice to which the stakeholders alluded in their comments (*Chapter Seven*), the engineering regulators in Nigeria could make sustainability education an accreditation condition.

Similar to the role of the professional and regulatory bodies is that of university leaders and teaching staff. This role is rather obvious and warrants no expatiation. Suffice it to state that in HEIs where sustainability education has been well-received, university management and teaching staff played a significant role. Such potentiality of HEI leadership in the advancement of sustainability education is aptly captured in not only the sustainability education declarations but in other myriad intervention proposals (Coral, 2009; Watson *et al.*, 2013; Etse and Ingley, 2016). Hence, university leadership and engineering teaching staff in Nigeria are suitably poised to contribute towards the realisation of sustainability education in the Nigerian engineering curriculum. The only caveat, however, is on the need to capacitate the Nigerian engineering educators to have the requisite knowledge and skills to participate effectively in the teaching of sustainability to engineering students. Such measure can be undertaken by individual HEIs.

Introductory Sustainability-Titled Course

The proposed course entitled "*An Introduction to Sustainable Engineering in Nigeria*" aims to introduce Nigerian engineering students to some fundamentals and theories of sustainable engineering. It is an attempt to fill a gap that has been identified in the present study, i.e. the lack of a bespoke sustainable engineering course in the Nigerian engineering curriculum. The course is suggested to run as a common course subsuming and replacing the existing *Engineer in Society* module, which has been found to pervade the Nigerian engineering curriculum. The choice of the course title is informed by the need to reflect the Nigerian context and to situate sustainable engineering practice in Nigeria within a global setting. The main elements of the course structure are introduction, learning outcomes, assessment criteria, weekly topics and a reading list. The introduction provides a brief background to the course and states the purpose for which it is run. Such information does not only correspond with best practice in curricular development and course design, but also stimulates interest in a sustainability course (Heywood, 2005a). Similarly, learning outcomes and assessment criteria are all considered important descriptors of a course.

The choice of the fifteen weekly topics is based on the learning outcomes of the proposed course and on the assumption of a semester-long course. The topics have been chosen and arranged to progressively introduce the students to the ideals of sustainable engineering over a 15-week period. The first three topics (Weeks 1-3) invite the students to appreciate the rationale for sustainable engineering presenting the historical context and the underpinning philosophies of the field. These topics are essential to expose the students to some of the reasons for the ascendance of sustainable engineering and the need for its practice. It is assumed that only when students buy into the sustainability worldview will they be motivated towards sustainability literacy. The next three topics (Weeks 4-6) introduce the students to the tools of sustainable engineering with reference to systems thinking and the application of sustainable engineering in the real world. These themes which naturally follow the theoretical underpinnings seek to point the students in the direction of sustainable engineering principles, frameworks and methods. Having established the rationale for engineering sustainability, it is appropriate to consider how projects can be engineered sustainably.

The topic in Week 7 focuses on Nigeria and seeks to underscore the relevance, application and likely challenges of sustainable engineering in the country. The topic is in line with the objects of contextual focus and local content highlighted by the stakeholders. Sustainability issues have been discovered to be better appreciated through context-relevant discussions (Jenneth and Ros, 2008; Lucena, 2013). The topics in Weeks 8, 9 and 11 feature a sustainable engineering activity and seminars as part of the PBL and PjBL approaches adopted in the course. These are intended to give students an opportunity to work out learning needs and to connect learning with the outside world. Weeks 10 and 12 feature themes adapted from Allenby's (2012) topics proposal for a sustainable engineering course. These topics are considered important in the Nigerian context given the broad focus of the *ESEM* and the essence of *The Engineer as Leader*. For Weeks 13-15, a collaborative sustainable engineering project is proposed to encourage teamwork and the ability to conceive, design and implement an engineering project sustainably.

The reading list provided at the end of the outline has been drawn in line with the purpose of the proposed course. The textbooks are intended to broaden the students' knowledge of the field and to expose them to the extensive scholarly work that has been undertaken in the area. Each textbook on the reading list is considered an important resource in the understanding of the fundamental concepts and theories of sustainability and sustainable engineering. Although the works have mainly been undertaken in the developed world context, this fact does not necessarily diminish their relevance to an introductory course on sustainable engineering for the Nigerian engineering curriculum. The wide-ranging issues covered in the textbooks including references to other works will provide the students with a rich content from which to study further. However, it is desirable to have similar scholarly works in the Nigerian context featured on the reading list. Presently, such works are rare, and it would be an interesting future work to produce a sustainable engineering textbook in the Nigerian context.

Contrasting Students' Pre-Workshop Test Scores

The pre-workshop sustainability test recorded strikingly similar overall mean scores for both groups of students (PG=7.3, UG=7.2). Given that the highest possible score on the test was 20, a low level of sustainability knowledge is inferred. Furthermore, an almost equal level of sustainability awareness amongst the students in both categories is deduced. The findings of *Chapter Five* have already shown that Nigerian engineering students irrespective of academic status generally exhibit a low level of sustainability knowledge. Students tend to be largely unaware of sustainability issues especially before an intervention. This could, therefore, account for the poor performance of the students on the pre-workshop sustainability test. Interestingly, some undergraduate students on the test had a fair idea of sustainability pillars which totally eluded the postgraduate students. Although just two undergraduate students listed all the pillars of sustainability correctly (possibly copied from each other) the fact that none of the postgraduate students could mention even one of the three sustainability pillars indicates a worrying gap. The implication is that sustainability education intervention at postgraduate level is as important as an intervention at undergraduate level.

Another remarkable contrast between the undergraduate and postgraduate students relates to the highest score recorded on the pre-workshop sustainability test. For the undergraduates it was 16 out of 20, whilst the postgraduates had a top score of 11. This suggests that at least one undergraduate student, who might have learned about sustainability via media sources (*Chapter Seven*), had a relatively good knowledge of the sustainability issues highlighted on the test. The importance of alternative sources of sustainability knowledge such as Internet and TV is noteworthy. The postgraduates' comparatively low top score is indicative of an across-the-board unacquaintance with the basics of sustainability. Nevertheless, all the postgraduate students except one effortlessly provided appropriate sustainability project examples; the undergraduate students could not satisfactorily illustrate such projects. Familiarity with real-life projects, perhaps through involvement in engineering works, might have enhanced the chances of the postgraduate students to offer these examples. Additionally, justifying sustainable engineering was particularly more difficult for the undergraduate students than it was for the postgraduate students, albeit trivially. This could have resulted from a difference in levels of critical reasoning skills coupled with poor sustainability knowledge. Overall, the findings of the pre-workshop test point to the need for an intervention.

Outcome of the Sustainable Engineering Activity

The outcome of the sustainable engineering activity undertaken by the students during the workshop was encouraging. All the students grasped the purpose and teaching point of the activity. Nevertheless, some observations are made with respect to the students' responses. An important observation is that students readily distinguished environmental issues for the railway project in the sustainable engineering scenario. Conversely, students struggled to discern social and economic concerns relevant to the given scenario. This suggests that whereas environmental aspects of sustainability are easily identifiable, social and economic issues are not. However, this is not quite unexpected given the currency of environmental sustainability as documented in the literature and reported in the present study (*Chapters Two* and *Three*). The implication of this observation for a sustainable engineering course is that learning techniques must be geared towards training students to recognise all possible sustainability issues of a project. One way of achieving such objective is through interactive strategies which the workshop did not adequately accentuate.

An additional point noted from the sustainable engineering activity is the failure of the students to mention possible mitigating measures of the sustainability challenges. This might have occurred due to a flaw in the design of the sustainable engineering activity. Alternatively, the omission might have been a consequence of students' inability to properly understand the task instruction. However, since a few of the students mentioned some possible extenuation of the identified issues, the oversight could not have resulted from instruction ambiguity. Nonetheless, to achieve optimum outcomes sustainable engineering activities should be designed in a way that minimises communication gaps. In terms of contextual relevance, some students mentioned a few social issues that could ensue from the railway project example, such as reduced kidnapping incidents,[36] loss of family ties, etc. This is an evidence of not only thinking outside the box but also of appropriately contextualising a problem. The implication for the trialled course is that such mode of thinking should be encouraged in sustainable engineering courses.

[36] Kidnapping incidents along Kaduna – Abuja road soared in 2017 with cases reported on a daily basis. Travellers resorted to journeying by train in order to outmanoeuvre the criminals.

Contrasting Students' Post-Workshop Test Scores

The difference between the overall mean scores of postgraduate and undergraduate students on the post-workshop test is marginal (PG=14.2, UG=13.5). Generally, the post-workshop performance of the two student groups is impressive given the highest possible score of 20. Nonetheless, some undergraduate students still struggled to define sustainability with one of them utterly failing to delineate the concept. The postgraduate students, on the other hand, evinced a reasonable grasp of the sustainability definition, even though one of them also misrepresented the concept. Interestingly, both groups of students were able to list the three pillars of sustainability. Furthermore, there was an impressive attempt by both groups to define sustainable engineering, which yielded the same mean score of 3.4. All students made a modest effort to justify sustainable engineering scoring an average of 50% on the justification question. With the exception of one undergraduate participant, all students grasped how to typify sustainable engineering projects. The highest scores amongst undergraduate and postgraduate students were 17 and 18 respectively.

The outcome of the post-workshop test reveals fairly good knowledge of the five sustainability-related questions. The small margin between the overall mean scores of the two student groups is indicative of the students' potential to learn regardless of academic level. By and large, the post-workshop scores portray a student group that is willing to learn, but still facing some difficulties. The ability of the students to reproduce the three pillars of sustainability suggests that learning has taken place. However, the unsuccessful attempt of some students to define sustainability and sustainable engineering as well as justify sustainable engineering could be attributed to the complexities of these topics. Moreover, it could mean that the intervening lecture was inadequate for imparting such knowledge. These two constraints are important for running a sustainable engineering course. The lesson is that adequate time must be allotted to clarifying the basics of sustainability and justifying the field of sustainable engineering.

Comparing Pre- and Post-Workshop Test Scores

Comparing the pre- and post-workshop test scores based on a repeated measures t-test, a significant progress is evident in the performance of the two student groups. The undergraduate participants moved from an overall mean score of 7.2 to 13.5, whilst the postgraduate respondents had their overall mean score increase from 7.3 to 14.2. With a mean percentage increase of 88% for both groups of students, the marked improvement can be linked to an intervention, which, in this case, is the sustainable engineering workshop. The workshop manifestly facilitated the students' enhanced knowledge of sustainability. Some of the students had quite impressive percentage increments on the test with one undergraduate student's score increasing by 400%. This student had a paltry pre-workshop test score of 2 but eventually achieved a post-workshop test score of 10. Similarly, a postgraduate student who had scored 4 points on the pre-workshop test earned a post-workshop score of 14 points, gaining a 250% increment.

The potential of the introductory course to increase the sustainability knowledge of students is confirmed. Corroborating this is the outcome of the workshop evaluation survey in which the students unanimously agreed to have learned about sustainability from the workshop. Hence, an introductory sustainable engineering course is useful for teaching and learning about basic sustainability concepts. Another strength of the workshop and by extension the introductory course is a potential to make students appreciate the need to engineer projects sustainably in Nigeria. This fact is also deduced from the workshop evaluation survey and can be linked to the sustainable engineering activity featured in the workshop. The use of the Abuja - Kaduna railway project as a scenario in the classroom activity provided an apt setting for students to identify and relate meaningfully with the problem. Thus, localising sustainability issues is obviously an effective way of provoking not only interest in sustainable engineering but also original thinking based on cultural experiences of sustainability challenges.

Limitations

An important constraint of the research is that the proposed sustainability education intervention, especially the designed sustainability course, is limited to findings and interpretations in the present study. Although the suggested sustainable engineering course is informed by remarkable insights gained from various analyses in the study, it is not a flawless proposal. Subjectivity cannot be completely ruled out in the choice and structure of the course content. Hypothetically, it is conceivable that a different researcher may come up with a dissimilar course design given the same information. However, the fact that the Nigerian engineering curriculum has been established to offer no sustainable engineering module, an introductory course is considered most suitable. Nonetheless, at the point of implementation by COREN, the proposed course could benefit from deliberations of engineering academics and practitioners including deans and heads of engineering departments from all Nigerian HEIs. This could be done during one of the episodic reviews of the BMAS document, in which the new course is proposed to be inserted.

Some other limitations acknowledged in the study involve the design of the sustainable engineering workshop. The one-hour duration may be insufficient to adequately trial the introductory sustainability course. In particular, the 25 min allotted to the presentation session did not allow for an extensive discussion and explanation of sustainability and sustainable engineering issues. This constraint might have reduced the prospect of sustainability learning amongst the students as a few of them struggled with some questions on the post-workshop sustainability test. Failure to adequately treat the topics due to shortage of time could have been a contributing factor. However, the choice of the one-hour for the workshop was informed by the need to avoid overburdening the students and the objective of the workshop to provide a rudimentary sketch of sustainable engineering. Moreover, the overall performance of the students on the post-workshop test and the outcome of the workshop evaluation survey showed that time inadequacy might not have had any significant effects.

Another limitation of the study is the apparently small sample size for both categories of participants as well as the inherent constraint of pre- and post-test assessment. Regarding the sample size, a slightly higher number of participants (n=30) would have been more desirable to represent a typical Nigerian engineering class. However, the workshop's sample size (n=21) is not totally wide of the mark as some graduate and undergraduate (usually final year) engineering classes in Nigeria comprise a small number of students. Given the difficulty of recruiting participants, the sample size of the workshop is not only pragmatic but also potentially representative of a Nigerian engineering class. The issues of internal and external validity are raised in relation to the pre- and post-test assessment adopted in the study. This evaluation approach has the tendency to increase internal validity at the expense of external validity.

In the present study, threats to internal validity were envisaged from participants' prior sustainability knowledge. This concern was, however, disconfirmed by the overall low mean score of the students on the pre-workshop test; although two undergraduate students had an above-average score on the test attributable to learning resources other than HEI-based lessons (*Chapter Seven*). Interestingly, there was no noticeable change in the performance of the two students on the post-test. Additionally, the assessment quiz featured open-ended questions that provided no clue to the possible answers. Thus, the internal validity of the pre- and post-workshop assessment scores was safeguarded having ruled out external influences. With regard to the external validity of the study, it is difficult to ascertain the degree or strength of generalisability. However, two measures taken towards improving the external validity of the study were random sampling and normality tests. Random selection of the participants by means of the handbill had the advantage of reducing bias that could have arisen from a strictly purposive sampling. Additionally, the result of the normality test conducted on the sample showed that the data was normally distributed (p = 0.101 at $p < 0.05$). Hence, the external validity of the study was not compromised by the use of the pre- and post-assessment instrument.

Summary

This chapter proposed and formulated an intervention for the Nigerian engineering curriculum and also trialled key elements of the designed sustainability course to test its effectiveness and suitability. Intervention requirements for the curriculum were defined as holistic and espousing the hybrid method of intervention as well as multidisciplinarity targeting the common courses classification. This resulted in a bipartite intervention comprising a guideline and an introductory course entitled "*An Introduction to Sustainable Engineering in Nigeria*." Highlighted in the guideline were roles of government, regulators and professional bodies, university leaders, and teaching staff, whilst the sustainability course featured 15 weekly topics.

A sustainable engineering workshop was organised to trial an introductory course on sustainability in a typical Nigerian engineering class setting. The workshop involved two student groups: undergraduate (n=11) and postgraduate (n=10). The outcome of the workshop comprised mainly insights into the prospect of successfully running a sustainable engineering course. The results of the pre-workshop test revealed that both undergraduate and postgraduate students had a low sustainability awareness having earned nearly equal overall mean scores of 7.2 and 7.3 out of 20 respectively. Similarly, the overall mean scores of the two student groups on the post-workshop test were close at points 13.5 and 14.2 out of 20 for undergraduates and postgraduates respectively. The difference between the pre- and post-test scores was found to be significant based on a repeated-measures t-test for undergraduate students: $t(10) = 6.71$, $p < 0.001$, and for postgraduate students: $t(9) = 6.16$, $p < 0.001$.

Results of the workshop evaluation survey showed that all the students agreed to have learned about sustainability by participating in the sustainable engineering workshop. Furthermore, all the students indicated that participating in the workshop helped them to appreciate the need for sustainable engineering in Nigeria. The students were also unanimous in stating that they had enjoyed participating in the workshop. Lastly, all the students felt convinced of the need to introduce sustainable engineering education in Nigeria. Overall, the sustainable engineering workshop elicited a positive feedback for an introductory sustainable engineering course. Some of the lessons derived from the workshop included the need for an intervention at the postgraduate level as well as the appropriateness of incorporating systems thinking in the designed course. Another feedback from the workshop was the suitability of the sustainable engineering activity which aided in problem contextualisation. A key lesson of the workshop is the need to provide an adequate time for the course.

Chapter Nine

9 Conclusions, Contributions and Further Work

Introduction

The present study aimed to formulate a suitable sustainability education intervention for the Nigerian engineering curriculum. To achieve this aim, the research queried the current level of sustainability knowledge of the Nigerian engineering community, examined the sustainability content of the Nigerian engineering curriculum, and explored sustainability education interventions appropriate for Nigerian engineering curriculum. Various research methods and tools were employed to address these questions including a modified sustainability literacy test, stakeholder survey, and content analysis of engineering documents. The study equally featured a workshop trial of sustainable engineering course. The findings of the study were contained in *Chapters Five* to *Eight*. This chapter concludes the entire thesis and highlights the contributions and further work emanating from the study. It underscores the usefulness and expediency of the proposed sustainability education intervention for the Nigerian engineering curriculum.

Conclusions

Assessment #1: Current level of sustainability knowledge of the Nigerian engineering community

An assessment of the sustainability literacy of the Nigerian engineering community was conducted based on three criteria: level of UNDESD awareness; performance on a sustainability literacy test; and self-assessment of sustainability knowledge, and across three cohorts: students; educators; and practitioners. The categorical data resulting from the survey were analysed and subsequently synthesised to holistically gauge the sustainability literacy level of Nigerian engineering community. From these analyses several findings ensued (*Chapter Five*). The Nigerian engineering community was found to largely exhibit very low sustainability literacy with a significant majority performing abysmally on all the assessment criteria. There was an evidence of widespread ignorance of the UNDESD within the Nigerian engineering community with students being the most uniformed. The Nigerian engineering community were more familiar with economic topics than the social or environmental issues. The least known sustainability themes across the board were the crosscutting topics. Slight familiarity with environmental sustainability and the candidness of students to admit sustainability illiteracy were the unexpected findings of the study.

The findings corroborate the work of Azapagic *et al* (2005), reviewed in *Chapter Two*, which reported low level of sustainability knowledge amongst engineering students in Europe and America. Some studies (UNEP-MESA, 2009; Manteaw, 2012) have similarly exposed a widespread ignorance of global sustainability initiatives around the world, which raises concerns about the efficacy of such efforts. Therefore, obtaining comparable results for not only engineering students but also practitioners and educators in Nigeria suggests a crucial need for an intervention. However, such intervention cannot proceed with the view that the Nigerian engineering community are sufficiently informed about environmental issues, since the results of the present study have unpredictably revealed that such familiarity is not a given. Thus, even though it contradicts several researches (Hanning *et al.*, 2012; UNESCO, 2014), the discovery of poor familiarity with environmental sustainability within the Nigerian engineering community is instructive. It accentuates the need to ensure that an intervention achieves a balance amongst the dimensions of sustainability.

Assessment #2: Sustainability content of the Nigerian engineering curriculum

The sustainability content of the Nigerian engineering curriculum was analysed based on three engineering documents, namely official BMAS for engineering programmes, and engineering handbooks of two Nigerian HEIs. Additionally, the perspectives of engineering educators and students on the sustainability content of the engineering curriculum as operationalised in the Nigerian HEIs were examined. These data were tested against 37 sustainability topics obtained from an expert-derived list of sustainability themes (see *Chapter Four*). An outcome of the investigation (*Chapter Six*) was that the sustainability content of the engineering programmes was mostly low. The majority of the stakeholders strongly agreed that the sustainability themes were insufficiently covered in the Nigerian engineering curriculum. Also, environmental topics were found to be the most cited sustainability themes, whilst social concepts were the least stated. Most of the featured sustainability themes appeared in the traditional engineering management courses. Only the BMAS document mentioned sustainability competence as a learning outcome for engineering graduates.

The findings are not unexpected of an engineering curriculum that has not been deliberately embedded with sustainability themes as reviewed in *Chapter Three.* The results are, however, consistent with the works of GuNi *et al.* (2011) and Etse and Ingley (2016) who reported low sustainability content in the academic programmes of African universities. Interestingly, studies outside the African continent, in regions with supposedly visible engineering sustainability education, have equally suggested an unsatisfactory sustainability content in a number of engineering programmes (Lozano and Watson, 2013; Watson, et al., 2013). This implies that in addition to devising an education intervention for the Nigerian engineering curriculum, implementation efforts must be strategised to ensure continued support at every stage of the intervention. Similarly, the dominance of the environmental content in the Nigerian engineering curriculum corroborates several studies (Coral, 2009; Byrne *et al.*, 2010) stressing the need for a balanced sustainability education intervention. The presence of some sustainability themes in the engineering management courses point to the potential of subsuming such courses in an intervention as suggested by Allenby (2012).

Assessment #3: Suitable sustainability education intervention for the Nigerian engineering curriculum

An assessment of a stakeholder survey was conducted to explore the sustainability education interventions appropriate for the Nigerian engineering curriculum (*Chapter Seven*). The stakeholders acknowledged a lack of sustainability programmes in Nigerian HEIs. Media sources such as educational television and Internet were discovered to be a great means of acquiring sustainability knowledge. The common course of *Engineer in Society* was the most perceived sustainability-relevant course. Virtually all the listed courses were biased towards environmental sustainability, and none had a sustainability title. Stakeholders expressed an overwhelming support for sustainability in terms of the need for involvement of Nigerian engineers, the need for sustainability expertise and the importance of sustainability in engineering education. The relevance of the various intervention approaches were viewed in the descending order of core, common, cross-disciplinary and discipline-specific courses. Emergent themes from the comments of the stakeholders were approach, focus area, challenge and imperative, all of which contributed to the formulation of a sustainability education intervention.

Findings such as the lack of sustainability courses/degrees in the Nigerian engineering curriculum are plausible reasons for an intervention. However, studies have shown that sustainability courses/degrees are not designed and embedded into engineering programmes simply as a result of their absence (Azapagic *et al.*, 2005; Allenby *et al.*, 2009; Murphy *et al.*, 2009). In addition to political will, the evidence-based strategies reviewed in *Chapter Two* are critical to a successful sustainability intervention. Stakeholder participation and use of pedagogical techniques including the conversion of the common courses into sustainability courses are important components of an intervention. The prospect of an intervention in the Nigerian engineering curriculum is propitious as the stakeholders are favourably disposed to engineering sustainability. This finding confirms previous studies regarding stakeholder interest in sustainability issues (Mcfarlane and Ogazon, 2011; UNESCO, 2012; Fadeeva *et al.*, 2014). With such an overwhelming support for sustainability by the engineering community in Nigeria, the likelihood of devising a successful sustainability education intervention is high.

Contributions

Contribution #1: Bipartite Sustainability Education Intervention

A bipartite sustainability education intervention which consists of a guideline and an introductory course entitled "*An Introduction to Sustainable Engineering in Nigeria*" was devised for the Nigerian engineering curriculum (*Chapter Eight*). Requirements for the intervention were defined as holistic and espousing the hybrid method (top-down and bottom-up) as well as multidisciplinary approach targeting the common courses. These resulted from the findings of the study and the reviewed literature. The guideline is a set of steps that can be followed to ensure a successful implementation of the intervention. It covers roles of government, regulators and professional bodies, university leaders, and faculty, whose relevance has been established in sustainability education research (*Chapters Two* and *Three*). The proposed sustainability course features 15 weekly topics ranging from the foundational issues of rationale and principles down to the elaborate ideas of earth systems engineering. PBL, PjBL and other pedagogical techniques are encapsulated in the designed course. Aspects of the course trialled in a workshop were unanimously appreciated by participants.

Contribution #2: Alternate Sustainability Literacy Test

Testing the sustainability literacy of individuals is an important aspect of sustainability education research. Most sustainability literacy tests feature a set of multiple choice questions with four or five alternative answers. The '*true/false/don't know'* format is seldom used on a sustainability literacy test for the demerit of random guessing by respondents. The sustainability literacy test employed in the present study (*Chapter Five*) featured the '*don't know'* option alongside the *true/false* choices to mitigate the threat of guesswork. However, this required a caveat urging test takers to be as honest as possible with their answers since no penalties were due for any of the options. This measure proved successful as no random guessing pattern was detected on the sustainability literacy test. Other factors that informed the design of the test were unsuitability of the existing test tools with the purposes of the present study (such as probe of sustainability fundamentals), time and resources. These factors were catered for in the resulting sustainability literacy test. Therefore, the modified test instrument can be utilised to test foundational sustainability knowledge especially where time and resources are limited.

Contribution #3: Content Analysis of Nigerian Engineering Documents

Content analysis as a way of gauging the spread or coverage of sustainability in an engineering curriculum is quite common in sustainability education research. Most of the curricular assessments relating to sustainability content have focused on the engineering curriculum in the form of documents published online by universities. However, such analyses are normally complemented by a stakeholder survey to account for the aspects of sustainability content that may have been missed on the websites of the universities. Curricular sustainability content analysis provides for an objective evaluation of the curriculum, but the curricular stakeholder survey assesses the subjective experience of stakeholders. Whilst a number of sustainability content analyses have been conducted on the engineering curricula of several HEIs around the world, the Nigerian engineering curriculum, prior to the present study, had not been assessed for sustainability content (*Chapter Three*). Hence, the sustainability content analysis of the Nigerian engineering documents undertaken in the current research (*Chapter Six*) is an invaluable baseline resource for future sustainability education research in Nigeria.

Contribution #4: Extension of Sustainability Education Research

Sustainability education research in the context of Nigerian engineering education is an extension of a study area with a history of developed world focus (*Chapter Two*). By examining the issues around sustainability education in the Nigerian engineering curriculum, the present study contributes to the continuing sustainability education discourse. This is especially relevant to the Nigerian engineering education community as the current research presents an opportunity to improve the engineering curriculum through the various sustainability education techniques. Furthermore, the research is useful in drawing the attention of educational authorities in Nigeria to develop a sustainability education framework as required in the numerous pacts ratified by the country's leadership. Additionally, the study is a contribution to the existing knowledge on sustainability education since it revealed some country-specific details about the prospects and challenges of sustainability education in Nigeria. The recommended sustainability education intervention (*Chapter Eight*) is actionable at various levels of command within the Nigerian educational authority structure.

Contribution #5: Workshop Trialling of Sustainable Engineering Course

The several approaches adopted in sustainability education research to measure the impact of a sustainability course have generally been in a post-intervention context. These are mostly full-fledged courses run over a semester in a community that is reasonably sustainability literate. In a pre-intervention context compounded by want of time and resources, it is nearly impossible to design, implement and assess the impact of a sustainability course. The workshop trial employed in the present study (*Chapter Eight*) provided a way around these constraints. It enabled the trial of aspects of the designed sustainable engineering course in a typical Nigerian engineering class setting. The outcome of the workshop satisfactorily served the purposes of the present study and indicated the usefulness of workshops as a means of trialling a sustainability course. Thus, where time and resources are insufficient, a sustainable engineering workshop can be organised to trial an introductory sustainability course.

Further Work

Further Work #1: Conversion of the Designed Course into a Postgraduate Sustainable Engineering Programme

An important realisation from the present study was that a sustainable engineering programme at the postgraduate level was needed. There was almost no difference between the sustainability knowledge of postgraduate and undergraduate students. Similarly, the educators and practitioners displayed scant sustainability knowledge. Although the recommended introductory sustainability course can be taught at both educational levels, the course is designed for inclusion in the BMAS document and engineering handbooks of Nigerian HEIs. These documents are generally details of undergraduate programmes. However, the proposed sustainable engineering course can be upgraded to a postgraduate level programme either as a certificate course or a degree programme. Educators and practitioners could benefit from such courses. Nonetheless, this may require extensive consultations with stakeholders as well as insights gained from recognised postgraduate sustainable engineering programmes across the world. Study could be conducted in the future to achieve this goal.

Further Work #2: Assessment of the Influence of Religious Values on Sustainability Interest in Nigeria

One of the challenges encountered in the present study was a disinclination of some stakeholders to participate in the research for socio-religious reasons. The disobliging individuals expressed strong objection to the concept of sustainability for contradicting the divine attributes of sustenance and providence. Religious issues could be a barrier to sustainability if the adherents of a religion fail to align their religious values with sustainability principles. In the incident reported in the present study, the main point of the religious argument was that the Earth needed no human protection since God who made it will sustain it. Being a deeply religious society, Nigeria might be populated by a fair number of people who share this view. Insights from the educational aims discussed in *Chapter Two* would suggest the presence and potency of education for salvation. Such educational aim could either facilitate or hinder sustainability education efforts. The possibility of this eschatological educational paradigm influencing some members of the Nigerian engineering community against sustainability research is disquieting. It begs the question of how many engineering stakeholders in Nigeria are averse to sustainability issues for socio-religious reasons. A related question could be how pervasive is the religion-induced aversion to sustainability concepts across the Nigerian society. Future research could seek some answers to these questions.

Further Work #3: Invitation of Nigerian HEIs to Register and Undertake the Sulitest

The Sulitest, which is the web-based international literacy test instrument developed to examine global awareness of core sustainability knowledge and skills, is suitable for higher levels sustainability literacy. The tool is supported by the UN and has been used by at least 612 educational institutions from around the world. An advantage of the Sulitest is that it provides a potent database useful in mapping the current state of sustainability literacy. Participating universities can also use the test results to monitor progress of sustainability education initiatives over time. However, participation on the test requires an official registration. Interestingly, no Nigerian HEI has registered to use the Sulitest.[37] In the future, when Nigerian HEIs will have adopted the designed sustainability course of the present study, they could register to undertake the Sulitest.

[37] https://www.sulitest.org/en/list-university.html

The outcome of the online sustainability test could form part of a future research to gauge the impact of the implemented sustainability course.

Summary

This chapter concluded the present thesis and presented the contributions and further work ensuing from the research. Evidence of scant sustainability knowledge of the Nigerian engineering community and inadequate sustainability content of the Nigerian engineering curriculum was found in the study. A bipartite intervention consisting of a guideline and an introductory sustainable engineering course was proposed as an implementation strategy. The contributions of the research included development of an alternate sustainability literacy test, creation of a baseline database from the content analysis of the Nigerian engineering curriculum, and extension of sustainability education research. Design of a postgraduate sustainable engineering programme, assessment of socio-religious impact on sustainability interest in Nigeria, and invitation of Nigerian HEIs to register with the Sulitest are studies that can be undertaken in the future.

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Appendix I

Assessment Instrument for Sustainability in Higher Education

AISHE 2.0 **Score Form**		Organization	
Name		Department	
Function	Manager / Researcher / Teacher / Student / Other	Date	

Identity	0/?	1	2	3	4	5	Remarks
I-1. Vision & Policy							
I-2. Leadership							
I-3. Communication							
I-4. Expertise							
I-5. Coherence							
I-6. Transparency & Accountability							

Operations	0/?	1	2	3	4	5	Remarks
O-1. Goals							
O-2. Structure							
O-3. Economy							
O-4. Ecology							
O-5. Humanity							
O-6. Quality Assessment							

Education	0/?	1	2	3	4	5	Remarks
E-1. Goals							
E-2. Methodology							
E-3. Awareness & Basics							
E-4. Thematic integration							
E-5. Interdisciplinary integration							
E-6. Output assessment							

Research	0/?	1	2	3	4	5	Remarks
R-1. Goals							
R-2. Methodology							
R-3. Awareness & Basics							
R-4. Thematic integration							
R-5. Interdisciplinary integration							
R-6. Output assessment							

Society	0/?	1	2	3	4	5	Remarks
S-1. Goals							
S-2. Methodology							
S-3. Awareness & Learning							
S-4. Thematic involvement							
S-5. Connecting							
S-6. Impact assessment							

Appendix II

ARISE Framework

Subject	Issue
What it is about?	T*he state we want to see*
Vision and mission	• The management of the organization has formulated a clear mission and vision on social responsibility. These are publicly supported in a broad and provable way
	• The profile of the organization has been designed in collaboration with different stakeholders
	• The organization has a clear vision on its intended added value for the users of its services in education, research, and service to society.
Policy	• The organisation has translated the mission and vision into concrete policy
	• The management of the organisation is explicitly responsible for the policy on social responsibility
	• The responsibility for implementing the policy is clearly and provably delegated in the organization
Education	• in developing its educational portfolio the management takes into account its objectives of social responsibility
	• The organisation stimulates the study programs to integrate relevant aspects of social responsibility into the content of the study programs.
	• The organisation has an explicit SR policy for its internationalization activities
Research	• in developing research portfolio the management takes into account its objectives of social responsibility
	• The organisation stimulates the research entities to integrate social responsibility issues into their research study programs and activities
Service to Society	• in developing its services the organisation takes on a perspective of social responsibility
	• The organization has an active dialog with its clients/partners on social responsibility
Operations/Planet	• the organisation has a clear view on its sphere of influence on the planet side of its operations
	• The organisation has a policy and concrete targets comprising a neutral or positive impact on its physical environment
	• The approach leads to tangible results
Operations/People	• the organisation has a clear view on its sphere of influence on the people side of its operations
	• The organisation has policy and concrete targets regarding the social quality of the organization
	• The approach leads to tangible results
Operations/Prosperity	• the organisation has a clear image of its sphere of influence on the financial side of its operations
	• The organisation has policy and concrete targets comprising a responsible financial continuity
	• The approach leads to tangible results

Subject	Issue
Students	• The organisation communicates clearly to (potential) students the level, status, content, and names of study programs
	• The organisation deals with its students in a provable responsible manner
	• The organisation explicitly pays attention to students with a particular background, like international students or students from minority groups
Professional field	• The organisation communicates to future and current employers regarding level, status, content, and names of study programs
	• The organisation has relations with educational institutions, organisations, and businesses in the region, focused on strengthening the societal meaning of education, research, and service to the community
Culture	• The social responsibility of the organisation is supported and shared by the majority of employees in the organization
	• The organisation communicates its targets and results with respect to the social responsibility of the organisation systematically, within and outside the organisation

Appendix III

GASU Framework: Modified GRI with Educational Dimension

	Category	Aspect
Economic	Direct Economic Impacts	Customers
		Suppliers
		Employees
		Providers of capital
		Public sector
Environmental	Environmental	Materials
		Energy
		Water
		Biodiversity
		Emissions, effluents, and waste
		Suppliers
		Products and services
		Compliance
		Transport
		Overall
Social	Labour Practices and Decent Work	Employment
		Labour/management relations
		Health and safety
		Training and education
		Diversity and opportunity
	Human Rights	Strategy and management
		Non-discrimination
		Freedom of association and collective bargaining
		Child labour
		Forced and compulsory labour
		Disciplinary practices
		Security practices
		Indigenous rights
	Society	Community
		Bribery and corruption
		Political contributions
		Competition and pricing
	Product Responsibility	Customer health and safety

		Products and services
		Advertising
		Respect for privacy
Curriculum		
SD incorporation in curricula		
CU1 Number and percentage (in respect to the total) of courses related to sustainability concepts		CU6 List with course titles and SD theme contained
CU2 Number of students enrolled in sustainability-related courses		
CU3 Number of courses with some content on SD themes		
SD capacity building		
CU4 Specific course to 'Educate the Educators' in SD		CU7 Course structure, goals and duration
SD monitoring in curricula		
CU5 Management procedures to monitor incorporation of SD themes into Curricula		CU8 Management structure and incorporation follow up procedures, continuous improvement methods, etc.
Administrative support		
		CU10 Administrative support (with a detailed plan and budget)
		CU11 Number and percent of departments and colleges including sustainability courses and curricula
Research		
RE1 Research in the area of sustainability		RE6 List issues addressed: Renewable energies, ecological economics, urban planning, etc
RE2 Percentage of graduate students doing research in sustainability		RE7 List of knowledge field involved.
RE3 Percentage of faculty doing research in sustainability issues		RE8 List of faculty members and Departments or Centres to which they belong.
RE4 Institutional support and management procedures for multidisciplinary and interdisciplinary research in sustainability		RE9 Type of support provided: budget allocation, office and personnel especially dedicated, etc.
RE5 Number of research projects that are multidisciplinary and interdisciplinary in the area of sustainability		RE10 List of Departments and Centres involved
Grants		
		RE11 Total revenues from grants and contracts specifying sustainability-related research
Publications and products		
		RE12 Published research with focus on sustainability-related issues
Programmes and centres		
		RE13 Number and function of centres on campus providing sustainability-related research or services

Appendix IV

Calculation of Survey Population

Estimation of Student Population

Programme	COREN-stipulated max no of students per level	Max no of students per course (5 levels)	No of HEIs offering course	Estimated total no of students per course
Aerospace Engineering	25	125	2	250
Agricultural Engineering	50	250	20	5000
Automotive Engineering	30	150	1	150
Biomedical Engineering	25	125	2	250
Ceramic Engineering	30	150	0	0
Chemical Engineering	50	250	28	7000
Civil Engineering	60	300	41	12300
Communication Engineering	50	250	5	1250
Computer Engineering	50	250	19	4750
Electrical and Electronics Engineering	50	250	45	11250
Environmental Engineering	40	200	7	1400
Food Engineering	40	200	5	1000
Gas Engineering	40	200	1	200
Production Engineering	40	200	5	1000
Industrial Engineering	40	200	1	200
Marine Engineering	40	200	4	800
Mechanical Engineering	50	250	44	11000
Mechatronics Engineering	30	150	6	900
Metallurgical and Materials Engineering	40	200	11	2200
Mining Engineering	40	200	1	200
Petrochemical Engineering	40	200	0	0
Petroleum Engineering	40	200	11	2200
Production Engineering	40	200	3	600
Public Health Engineering	40	200	0	0
Refrigeration and Air-Conditioning Engineering	30	150	0	0
Structural Engineering	30	150	1	150
Systems Engineering	40	200	1	200
Textile and Polymer Engineering	30	150	1	150
Water Resources Engineering	40	200	3	600
Wood Products Engineering	30	150	1	150
Estimated student population				**65150**

Estimation of Educator Population: The COREN recommended student/educator is 15:1. For a student population of 65,150, the educator population can be estimated thus: 1/15 x 65,150 = 4,343. Hence, the estimated educator population is **4,343**.

Estimation of Practitioner Population: Information obtained from COREN revealed that there are about **30,000** registered engineers in Nigeria.

Estimation of Population of Nigerian Engineering Community: The population of the Nigerian engineering community is estimated by summing the figures. This gives 65,150 + 4,343 + 30,000 = **99,493**.

Appendix V

Sample of Sustainability Literacy Test

1. Indicate whether the following statements are true or false. Tick the “Do not know” option if you are not sure of the correct answer.

Sustainability Literacy Test	True	False	Do not know
a. Ozone layer protects us from acid rain and temperature fluctuations	O	O	O
b. Carbon monoxide is one of the greenhouse gases that cause global warming	O	O	O
c. The main focus of the Kyoto Protocol adopted in 1997 was nuclear waste	O	O	O
d. Agenda 21 is a global treaty signed by UN member nations at the Stockholm Earth Summit in 1992	O	O	O
e. Global population stood at 1.6 billion in 1900	O	O	O
f. Less than 1 million people in the world have no access to clean drinking water			
g. Engineers’ role in sustainability suffices with ensuring that their designs or systems do not harm the environment	O	O	O
h. Long-term profitability is the most commonly used definition of economic sustainability	O	O	O
i. The review of global poverty line to US $ 1.90 was spurred by worldwide sustainability activisms	O	O	O
j. Economic development and environmental protection are mutually exclusive	O	O	O
k. The sustainability pillars of environment, society and economy are widely accepted to be in a hierarchical, rather than equal, relationship	O	O	O
l. In the landmark Brundtland Report of 1987, the terms *sustainability* and *sustainable development* are used interchangeably	O	O	O
m. Nigeria failed to ratify the UN 2030 Agenda for Sustainable Development in 2015 as presidential elections held in the country at the time.	O	O	O
n. Federal Environmental Protection Agency is the primary agency that oversees environmental regulation in Nigeria	O	O	O
o. Breeding of animals in zoos is the most significant driver in the loss of species and ecosystems around the world	O	O	O

2. Based on your response to the above questions, how would you rate your sustainability knowledge?

O Very poor **O** Poor **O** Average **O** Good **O** Very good

Appendix VI

Sample of Student Survey

Student Sustainability Survey

Part A. Demographic Information

1. **State your university & engineering programme** ....

   ....

2. **Which describes you best?** (*Please, put a cross in the appropriate circle*)

   O Undergraduate Student **O** Graduate Student – Master's Level

   O Graduate Student – Doctoral Level

3. **Please select your level** (if applicable)

   O 100L **O** 200L **O** 300L **O** 400L **O** 500L

4. **What is your sex?** **O** Female **O** Male

5. **Indicate the extent to which you disagree or agree with the following statements:**

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
a. Nigerian engineers should contribute to sustainable development	O	O	O	O	O
b. Sustainability expertise is a competence required of Nigerian engineers	O	O	O	O	O
c. Sustainability is important in engineering education	O	O	O	O	O

6. **Are you aware of the United Nations Decade of Education for Sustainable Development?**

   O Yes **O** No

Part B. Curricular Assessment

Sustainable development is defined as "development that meets the needs of the present generation without compromising the ability of future generation to meet their own needs" (WCED, 1987)

7. **Does your department offer a course, module or degree in sustainability, sustainable development, or sustainable engineering?** (*Please, put a cross in the circle*)

   O Yes **O** No

8. **Think about all the courses (including the common courses) you have taken in your engineering programme. Which courses do you believe addressed sustainability? Rank the top 3 courses in order of significant sustainability content.**

   (a)..

   (b)..

   (c)..

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9. **To what extent were the following *economic concepts* discussed in your engineering lectures?**

	Not at all	Slightly	Moderately	Strongly	To a great extent
	1	2	3	4	5
a. Gross National Product (GNP), Productivity	O	O	O	O	O
b. Resource use, exhaustion (materials, energy, water)	O	O	O	O	O
c. Finances and sustainable development	O	O	O	O	O
d. Production, consumption patterns	O	O	O	O	O
e. Developmental economics	O	O	O	O	O
f. Accountability	O	O	O	O	O

10. **To what extent were the following *environmental concepts* discussed in your engineering lectures?**

	Not at all	Slightly	Moderately	Strongly	To a great extent
	1	2	3	4	5
a. Environmental policy and law	O	O	O	O	O
b. Lifecycle assessment	O	O	O	O	O
c. Pollution, accumulation of toxic waste, and/or effluents	O	O	O	O	O
d. Biodiversity	O	O	O	O	O
e. Resource efficiency, eco-efficiency, and/or cleaner production	O	O	O	O	O
f. Climate change including global warming, air emissions, and/or ozone depletion	O	O	O	O	O
g. Resources use: depletion and/or conservation of materials, energy, and/or water	O	O	O	O	O
h. Land use: desertification, deforestation, erosion, and/or soil depletion	O	O	O	O	O
i. Alternative energy	O	O	O	O	O

11. **To what extent were the following *social concepts* discussed in your engineering lectures?**

	Not at all	Slightly	Moderately	Strongly	To a great extent
	1	2	3	4	5
a. Demography/population	O	O	O	O	O
b. Employment/unemployment	O	O	O	O	O
c. Poverty	O	O	O	O	O
d. Bribery and/or corruption	O	O	O	O	O
e. Equity and/or justice	O	O	O	O	O
f. Health	O	O	O	O	O
g. Politics	O	O	O	O	O
h. Education and training	O	O	O	O	O
i. Diversity and social cohesion	O	O	O	O	O
j. Culture and/or religion	O	O	O	O	O
k. Labour and/or human rights	O	O	O	O	O
l. Peace and security	O	O	O	O	O

12. **To what extent were the following *multi-dimensional concepts* discussed in your engineering lectures?**

	Not at all	Slightly	Moderately	Strongly	To a great extent
	1	2	3	4	5
a. People as part of nature and/or limits to growth	O	O	O	O	O
b. Systems thinking and applications	O	O	O	O	O
c. Responsibility	O	O	O	O	O
d. Governance	O	O	O	O	O
e. Holistic thinking	O	O	O	O	O
f. Long-term thinking	O	O	O	O	O
g. Communication and reporting	O	O	O	O	O
h. Sustainable development	O	O	O	O	O
i. Ethics and philosophy	O	O	O	O	O
j. Transparency (in design and/or decision-making process)	O	O	O	O	O

13. **Indicate the extent to which you have learned about sustainable development through:**

	Not at all	Slightly	Moderately	Strongly	To a great extent
	1	2	3	4	5
a. Your core engineering courses	O	O	O	O	O
b. Common engineering courses (incl. elective courses taken from 200L-500L) at your university	O	O	O	O	O
c. Participating in research at your university	O	O	O	O	O
d. Reading, listening to, or watching media sources (eg. news, educational television, radio, etc.)	O	O	O	O	O

14. **Indicate how appropriate you think the following ways of introducing sustainability education would be to your home department or university.**

	Not at all	Slightly	Moderately	Strongly	Extremely
	1	2	3	4	5
a. Integration of sustainability into existing core courses or programmes	O	O	O	O	O
b. Creation of new discipline-specific sustainability course or programme	O	O	O	O	O
c. Creation of new cross-disciplinary sustainability course or programme	O	O	O	O	O
d. Integration of sustainability into common/elective engineering courses	O	O	O	O	O

Appendix VII

Sample of Educator Survey

Educator Sustainability Survey

Part A. Demographic Information

1. **State your university & department** ……………………………………………………………………………

   ……

2. **State your engineering discipline**…………………………………………………………………………
3. **Please select your academic qualification.** (*Please put a cross in the appropriate circle*)

   O Bachelor's degree **O** Master's degree **O** Doctoral degree **O** Others (specify)……………

4. **What is your sex?** **O** Female **O** Male

5. **Indicate the extent to which you disagree or agree with the following statements:**

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
a. Nigerian engineers should contribute to sustainable development	O	O	O	O	O
b. Sustainability expertise is a competence required of Nigerian engineers	O	O	O	O	O
c. Sustainability is important in engineering education	O	O	O	O	O

6. **Are you aware of the United Nations Decade of Education for Sustainable Development?**

   O Yes **O** No

Part B. Curricular Assessment

Sustainable development is defined as "development that meets the needs of the present generation without compromising the ability of future generation to meet their own needs" (WCED, 1987)

7. **Does your university or department offer a course, module or degree in sustainability, sustainable development, or sustainable engineering?** **O** Yes **O** No

8. **Do you think sustainability is relevant to engineering education?** (*Please give reasons for your answer)*

9. **Think about all the courses you have taught. Which courses do you believe addressed sustainability? Rank the top 3 courses in order of significant sustainability content.**

   (a)……

   (b)……

   (c)……

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10. **To what extent do you address the following *economic concepts* in your teaching of engineering?**

	Not at all	Slightly	Moderately	Strongly	To a great extent
	1	2	3	4	5
a. Gross National Product (GNP), Productivity	O	O	O	O	O
b. Resource use, exhaustion (materials, energy, water)	O	O	O	O	O
c. Finances and sustainable development	O	O	O	O	O
d. Production, consumption patterns	O	O	O	O	O
e. Developmental economics	O	O	O	O	O
f. Accountability	O	O	O	O	O

11. **To what extent do you address the following *environmental concepts* in your teaching of engineering?**

	Not at all	Slightly	Moderately	Strongly	To a great extent
	1	2	3	4	5
a. Environmental policy and law	O	O	O	O	O
b. Lifecycle assessment	O	O	O	O	O
c. Pollution, accumulation of toxic waste, and/or effluents	O	O	O	O	O
d. Biodiversity	O	O	O	O	O
e. Resource efficiency, eco-efficiency, and/or cleaner production	O	O	O	O	O
f. Climate change including global warming, air emissions, and/or ozone depletion	O	O	O	O	O
g. Resources use: depletion and/or conservation of materials, energy, and/or water	O	O	O	O	O
h. Land use: desertification, deforestation, erosion, and/or soil depletion	O	O	O	O	O
i. Alternative energy	O	O	O	O	O

12. **To what extent do you address the following *social concepts* in your teaching of engineering?**

	Not at all	Slightly	Moderately	Strongly	To a great extent
	1	2	3	4	5
a. Demography/population	O	O	O	O	O
b. Employment/unemployment	O	O	O	O	O
c. Poverty	O	O	O	O	O
d. Bribery and/or corruption	O	O	O	O	O
e. Equity and/or justice	O	O	O	O	O
f. Health	O	O	O	O	O
g. Politics	O	O	O	O	O
h. Education and training	O	O	O	O	O
i. Diversity and social cohesion	O	O	O	O	O
j. Culture and/or religion	O	O	O	O	O
k. Labour and/or human rights	O	O	O	O	O
l. Peace and security	O	O	O	O	O

13. **To what extent do you address the following *__multi-dimensional concepts__* in your teaching of engineering?**

	Not at all	Slightly	Moderately	Strongly	To a great extent
	1	2	3	4	5
a. People as part of nature and/or limits to growth	O	O	O	O	O
b. Systems thinking and applications	O	O	O	O	O
c. Responsibility	O	O	O	O	O
d. Governance	O	O	O	O	O
e. Holistic thinking	O	O	O	O	O
f. Long-term thinking	O	O	O	O	O
g. Communication and reporting	O	O	O	O	O
h. Sustainable development	O	O	O	O	O
i. Ethics and philosophy	O	O	O	O	O
j. Transparency (in design and/or decision-making process)	O	O	O	O	O

14. **Indicate the extent to which you have taught sustainable development through:**

	Not at all	Slightly	Moderately	Strongly	To a great extent
	1	2	3	4	5
a. Core engineering courses of your department	O	O	O	O	O
b. Common engineering courses at your university	O	O	O	O	O
c. Supervising undergraduate or postgraduate research at your university	O	O	O	O	O
d. Pointing students in the direction of reading, listening to, or watching media sources (eg. news, educational television, radio, etc.)	O	O	O	O	O

15. **An important learning outcome for engineering programmes in Nigeria recommended by the Council for the Regulation of Engineering in Nigeria (COREN) is "ability to consider the environment and sustainability in finding solutions to problems". How do you rate the learning of sustainability skills by your graduating engineering students?**

O Very poor **O** Poor **O** Average **O** Good **O** Very good

16. **From your experience as an educator, indicate how appropriate you think the following sustainability education interventions would be to your department or university.**

	Not at all	Slightly	Moderately	Strongly	Extremely
	1	2	3	4	5
a. Integration of sustainability into existing core courses or programmes	O	O	O	O	O
b. Creation of new discipline-specific sustainability course or programme	O	O	O	O	O
c. Creation of new cross-disciplinary sustainability course or programme	O	O	O	O	O
d. Integration of sustainability into common/elective engineering courses	O	O	O	O	O

Appendix VIII

Sample of Practitioner Survey

Practitioner Sustainability Survey

Part A. Demographic Information

1. **State your engineering discipline**……………………………………………………………………
2. **State your academic qualification**……………………………………………………………………
3. **Which describes your employment?**

O Public Service O Private Organisation O Multinational Institution

4. **What is your sex?** O Female O Male
5. **State your years of professional experience**……………………………………………………………
6. **Are you aware of the United Nations Decade of Education for Sustainable Development?**

   O Yes O No

Part B. Miscellaneous Information

Sustainable development is defined as "development that meets the needs of the present generation without compromising the ability of future generation to meet their own needs" (WCED, 1987)

7. **Is sustainability an issue you consider in your engineering practice?** (*Please give reasons for your answer*).

8. **Indicate the extent to which you disagree or agree with the following statements**:

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
a. Nigerian engineers should contribute to sustainable development	O	O	O	O	O
b. Sustainability expertise is a competence required of Nigerian engineers	O	O	O	O	O
c. Sustainability is important in engineering education	O	O	O	O	O

9. **Indicate how appropriate you think the following sustainability education interventions would be to an engineering education curriculum.**

	Not at all 1	Slightly 2	Moderately 3	Strongly 4	Extremely 5
a. Integration of sustainability into existing core courses or programmes	O	O	O	O	O
b. Creation of new discipline-specific sustainability course or programme	O	O	O	O	O
c. Creation of new cross-disciplinary sustainability course or programme	O	O	O	O	O
d. Integration of sustainability into common/elective engineering courses	O	O	O	O	O

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Appendix IX

Definitions of STAUNCH® Sustainability Topics

Economic topics	Definition as employed in the present research
i. Gross National Product	Estimated total value of products & services produced in a given period by a country
ii. Resource use/exhaustion	Driver of economic growth consisting of material, energy and water uses
iii. Finances	Monetary resources of a state or an organisation
iv. Production	Process of transforming raw materials into goods & services
v. Developmental economics	Branch of economics dealing with aspects of development in low income countries
vi. Accountability	Responsibility to perform specific accounting function in an organisation
Environmental topics	
i. Environmental policy & law	Regulations guiding all environmental issues in a country or an organisation including standards and enforcement
ii. Lifecycle assessment	Holistic assessment of a project's lifespan (cradle-to-grave or –to-cradle)
iii. Pollution	Introduction of a harmful substance into the environment
iv. Biodiversity	Variety of flora and fauna interacting within a particular habitat or across the world
v. Resource efficiency	Sustainable use of Earth resources based on ecoefficiency & cleaner production
vi. Climate change	Large-scale, long-term shift in Earth weather patterns or average temperatures
vii. Resource use: depletion	Environmental cost of exploiting Earth resources including material conservation
viii. Land use: desertification	Resultant land use issues of deforestation, erosion and soil depletion
ix. Alternative energy	Renewable energy (other than fossil fuel) that is harmless to the environment
Social topics	
i. Demography & population	Study of human population and its dynamics, regionally and globally
ii. Employment & unemployment	The state of being or not being in a paid job and the discourse around these issues especially as regards teeming youth population
iii. Poverty	The state of being poor measured relative to a society's prevailing living standard
iv. Bribery & corruption	Exchanging money for illicit favours and abuse of power for personal gains
v. Equity & justice	Fair and equal treatment under law as well as equal distribution of societal wealth
vi. Health	Issues surrounding mental and physical well-being and healthcare services for all
vii. Politics	All activities associated with the governance of a country
viii. Education & training	All activities of acquiring knowledge, attitude and skills, formally and informally
ix. Diversity & social cohesion	Issues of varied social backgrounds and the need for solidarity and togetherness
x. Culture & religion	Differences in cultural and spiritual beliefs and the need for tolerance
xi. Labour & human rights	Basic rights and freedoms belonging to every person on Earth from birth until death
xii. Peace & security	Absence of conflict and safe from terrorism, crime, etc. locally and globally
Crosscutting topics	
i. People as part of nature	The ineluctable interlink among flora, fauna and humans as part of the ecosystem
ii. Systems thinking	Way of thinking that sees interrelationships and patterns of change holistically
iii. Responsibility	A moral obligation to behave appropriately in all situations and circumstances
iv. Governance	The action or manner of governing a state or an institution
v. Holistic thinking	Thinking in wholes as opposed to reductionist thinking (or mechanistic thinking)
vi. Long-term thinking	Thinking that considers reasonable or plausible pathways to the future
vii. Communication & reporting	Any form of academic writing and presentation as part of disseminating information to peers, the public and to authority
viii. Sustainable development	Meeting the needs of the present generation without comprising the ability of future generations to meet their own needs
ix. Ethics & philosophy	Ethical considerations including all forms of professional ethics and principles
x. Transparency	Principle of doing things openly rather than secretly

Appendix X

Sample of Invitation Letter for a Survey

LONDON'S GLOBAL UNIVERSITY

17th May 2017

Addressee

R.E USMAN AKEEL - UCL DOCTORAL RESEARCHER

This is a letter of introduction for Mr. Usman Akeel who is a doctoral researcher in the Department of Civil, Environmental and Geomatic Engineering at University College London (UCL), which is clearly shown on his UCL Student Identity Card.

Usman is undertaking research leading to the award of a doctorate on the subject of Sustainable Engineering Education in Nigeria. The research is aimed at developing a sustainable engineering education framework for higher education institutions in Nigeria (HEIs). The study will assess sustainability literacy, sustainability curricular content and sustainability attitude of the Nigerian engineering community (students, educators, practitioners).

Your university is one of the four Nigerian HEIs identified as possible case studies in this project based on excellent academic record and innovation in engineering education. Accordingly, Usman would like to invite you to assist with this research by involving your students and educators in the completion of a questionnaire.

Please be assured that any information provided will be treated in the strictest confidence and none of the participants will be individually identifiable in the resulting thesis, report or other publications. Participants are entirely free to discontinue participation at any time or to decline to answer particular questions.

The outcome of the study will benefit participants in several ways including an appreciation of their sustainability knowledge and disposition towards sustainability education in Nigeria.

For further information, please contact the principal supervisor, Dr Sarah Bell, by email at s.bell@ucl.ac.uk or telephone on +44(0)2076797874.

Yours faithfully

[redacted]

Dr Sarah Bell
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University College London

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Appendix XI

Stakeholder-Provided List of Sustainability-Related Courses

Engineer in Society	Transport Phenomena	Machine Design	Extractive Metallurgy	New Building
Environmental Impact Assessment	Digital Signal Processing	Materials for Energy Storage	Financial Management	Systems Development
Environmental Health	Economic Dispatch	Metallurgical & Mat Eng	Geo-Environmental Engineering	Systems Design
Research Methodology	Embedded System	Nanotechnology	Heat & Mass Transfer	Tech Policy & Dev
Entrepreneurship & Innovation	Foundry	Network Management	Intelligence Circuits	Vibration
System Reliability	Highway Engineering	Petroleum Economics	Internal Combustion Engine	Welding
Wastewater Management	Iron & Steel Making	Quality Control	Introduction to Chemical Engineering	Fluid Mechanics
Environmental Pollution & Control	Optimisation Techniques	Reaction Engineering	Irrigation	Geotechnical Engineering
Engineering Economics & Law	Process Control	Reservoir Asset Management	Less Common Separation Process	Engineering Geology
Production	Structural Engineering	Unit Operations	Manufacturing Process	Statistics for Engineers
Management	Applied Electronics	Water Res Engineering	Measurement of Eng Works	Environmental Management
Engineering Design	Boundary Theory	Wireless Communication	Mechanical Engineering	Env Science & Eng
Material Science	Building Construction	Advanced Programming	Meteorology	Engineering Analysis
Solid Waste Management	Computer Network	Aerodynamics	Object Oriented	Solid Work
Engineering Thermodynamics	Mechanics of Machine	Air Condition & Refrigeration	Petroleum Technology	Corrosion Engineering
Integrated Water Res Management	Project Management	Airport Engineering	Polymer Science & Technology	Engineering Ethics
Mineral Processing	Renewable Energy	Assembly Lang Programming	Population Ecology	Energy Studies
Power & Machine	Sewage Recycling & Mgt	Atomic Spectra	Proc Modelling & Optimisation	Solid Mechanics
Building Info Modelling	Survey	Biotechnology	Productivity	Civil Engineering Practice
Control Engineering	Transport Engineering	Business & Wealth Creation	Radar Communication	Electromagnetic Theory
Developmental Economics	Advanced Mathematics	Business Creation & Growth	Reinforced Concrete Design	Solar Energy
Environmental Engineering	Biofuels	Casting & Fabrication	Reservoir Engineering	Electromagnetism
Material Engineering	Blding & Const Mgt	Ceramics	Rural Water Supply	Strength of Materials
Reliability & Maintainability	Building Tech & Env Control	Chemical Reaction Kinetics	Safety	Electromagnetic Waves
Biomaterials	Civic Education	Computation Intelligence	Services	Dynamic of Compressible Flow
Composite	Communication Techniques	Concrete Technology	Soil & Water Conservation	Soil Mechanics
Construction Management	Construction Technology	Design & Fabrication	Soap & Detergent Tech	
Energy Conversion System	Electrical Machine	Distributed Generator Element	Soft Computing	

Appendix XII

Sample of Pre-Workshop Sustainability Test

First Name Only:

1. **How would you define sustainability or sustainable development?**

2. **What are the pillars of sustainable development?**

3. **How would you define sustainable engineering?**

4. **How would you justify the need for sustainable engineering?**

5. **Give three examples of projects that can be engineered sustainably.**

Appendix XIII

Sample of Post-Workshop Sustainability Test

First Name Only:

1. **How will you now define sustainability or sustainable development?**

2. **What are the pillars of sustainable development?**

3. **How will you now define sustainable engineering?**

4. **How will you now justify the need for sustainable engineering?**

5. **Give three examples of projects that can be engineered sustainably.**

Appendix XIV

Sample of Workshop Evaluation Survey

First Name Only:

1. Reflect on the Sustainable Engineering Workshop you just completed. Determine the extent to which you disagree or agree with the following statements:

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
a. Participating in the Workshop helped me learn about sustainability concepts	O	O	O	O	O
b. Participating in the Workshop helped me appreciate the need for sustainable engineering in Nigeria	O	O	O	O	O
c. I enjoyed participating in the Workshop	O	O	O	O	O
d. I am convinced that sustainable engineering education should be introduced into Nigerian engineering curriculum	O	O	O	O	O

2. Suggest any topics or subjects for inclusion in a sustainable engineering module or course in Nigerian engineering education curriculum.